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Working Paper 2.1 Part I
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PART I. Trends in Average Length and Weight, and Proportion Mature at Age for Relevant Stocks and Trends in Environmental Variables

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This paper addresses TOR 2.1 Trends in Stock Productivity:

a.) For relevant stocks, identify trends in biological parameters (i.e., life history and/or recruitment) and assess their importance for the computation of BRPs and for specification of rebuilding scenarios;

b.) If possible, summarize trends in pertinent environmental variables that might be related to the trends in those biological parameters relevant to BRPs.

Introduction

During the 2005 GARM II assessment meeting (Mayo and Terceiro 2005), declining trends in commercial mean weights at age were observed in recent years for some groundfish stocks. If trends in growth are significant and persistent there would be potential ramifications for stock assessments that involve stock projections or calculation of biological reference points (BRP). This was the impetus to form a GARM working group to examine trends in length, weight, and maturity of the managed groundfish stocks.

The working group has three major objectives: 1) derive time series of population mean length, weight, and maturity at age for groundfish stocks using research survey data 2) perform statistical analyses to detect increasing or decreasing trends; and 3) explore potential mechanisms that may be influencing trends. Potential mechanisms effecting growth and maturity include, but are not limited to, maternal and paternal effects, stock density, environment, i.e. temperature and oceanographic conditions, prey abundance, and fishery induced selective mortality. In our future work, we will explore mechanisms related to density dependence, environment, and prey abundance only.

We have addressed the first objective and present here a compilation of trends in growth and maturity at age for twenty groundfish stocks, including most of the GARM stocks and several other selected groundfish stocks. We have initiated some statistical tests for detecting trends and will continue those analyzes further in conjunction with exploring potential mechanisms for trends in growth.

Methods

Length, weight, and maturity data, as well as age structures for twenty groundfish stocks collected on NEFSC winter (1992-2006), spring (1963-2005) and autumn (1963-2005) research bottom trawl surveys, using standard groundfish procedures (Azarovitz 1981), were analyzed in this study. The twenty stocks analyzed included: Georges Bank (GB) cod, GB haddock, GB yellowtail flounder, Southern New England yellowtail flounder (SNE) Gulf of Maine-Cape cod yellowtail founder, (GM-CC), Gulf of Maine (GM) cod, witch flounder, American plaice, GM winter flounder, SNE-Middle Atlantic (MA) winter flounder, GB winter flounder, white hake, Pollock, redfish, as well as 5 other stocks stocks: butterfish, fluke (summer flounder), herring, mackerel, and northern GB silver hake (Table 6.1). Time series varied in length between the stocks based on the available age data. The longest time series was from 1963-2005 (GB haddock) and the shortest was from 1982-2007 (witch flounder).

Stratified mean length at age, mean weight at age, and mean age compositions (number per tow at age), were estimated for each stock using standard NEFSC survey analysis software (SURVAN). Stratified mean length and weight at age for the flatfish stocks were estimated separately for females and males because flatfish exhibit dimorphic growth by sex. Mean weights at age for each stock prior to 1992 were estimated using the stock-specific length-weight equation applied in each of the assessments. Means weight at age since 1992 were of particular interest because individual fish weights have been recorded on NEFSC research bottom trawl surveys since that time. The length-weight model: $\ln(W) = a + b\ln(L)$, where W is body weight (kg), L is total length (cm) and a and b are parameters, was fit to these data to derive mean weights at age annually for each stock and survey. Mean lengths and weights at age were re-scaled as Z-scores [(observed – mean)/ standard deviation] for easier visual comparison of trends among ages. A loess smoother with a tension of 0.5 was also fit to the stratified mean length and mean weight at age for each stock.

Logistic regression analysis was used to estimate female maturity ogives from NEFSC research survey data for the season nearest the time of spawning. The number of samples taken each year, by sex, over the time series is not consistently high for most stocks and does not allow for reliable annual estimates, so the data was smoothed using either a 3- or 5-year moving average. For example, the 1990 ogive was estimated by combining data from 1989-1991 and estimating one ogive, and then the 1991 ogive was estimated by combining data from 1990-1992 and so forth, for the time series. This means that the first year e.g., 1970, only as two years of data (1970, 1971) and the last year, 2007, also has only 2 years of data (2006 and 2007). Confidence limits for proportion mature at age were estimated at the 95% level using the approximate variance for large samples (Ashton 1972, O'Brien et al. 1993) and inverse 95% confidence limits for A_{50} (median age at maturity) were estimated within the SAS PROBIT procedure (SAS). The maturity ogives presented here are not necessarily used in the assessment.

To detect trends and patterns among ages and years the data were ranked by quintiles based on rank value by age group across years for each time series of mean length, mean weight, abundance, and proportion mature at age. The Visual Report (VR) software package (available in the NEFSC Stock Assessment Toolbox) was used to generate the quintile plots. Plotting symbols depend on quintiles of rank, i.e. annual values that fall into the lowest quintile (0-20%) are plotted in black and annual values in the highest quintile (80-100%) are plotted in red (Figure 2.1.1)

Linear regression was used to test the null hypothesis of no linear trend in mean length and weight at age for selected stocks. Statistical significance of estimated trends was also evaluated using randomization tests (Manley 1997) and simple standard regression statistics. Results were "statistically significant" in this analysis if the probability of Type I error for a two-sided test under the null hypothesis of no trend was $P \leq 0.1$. The critical value $P = 0.1$, was used (rather than $P = 0.05$, for example) because of noise in the survey data and concern about failing to detect trends.

For the randomization tests, Z-scores of mean length and weight for each age group, stock, and survey were reordered randomly and then regressed on year. Approximate two-sided probability *P*-values were computed as the proportion of randomized values that were as extreme, or more extreme than the observed test statistic (observed slope). A total of 1,000 randomizations were used to compute each *P*-value.

In addition to testing the significance of individual slopes, we used an "exact" binomial test for the null hypothesis of no trends and no correlation in trends among age groups for a single stock and survey. The exact test is a standard statistical approach based on the probability of seeing the observed or a larger number of positive or negative slopes from a set of linear regressions under the null hypothesis. Under the null hypothesis of no trends and no correlation, positive and negative slopes are equally likely. A significant exact test indicates that different age groups for a single stock and survey share the same trends. For example, if there were eight age groups for a stock with six positive trends in mean length and two negative trends in mean length , then the exact test would be not significant with $P = 0.29$. In this example, the *P*-value is the probability of getting 6, 7 or eight positive or negative trends under the null hypothesis. In contrast, if there were five age groups and all had positive slopes, then $P = 0.0625$ (significant). The binomial test is most useful with at least five size groups, because a significant p-value ($P <= 0.1$) can occur only with five or more size groups.

Environmental Data Series

We present time series of several global and regional environmental times series that may potentially influence change in growth parameters of groundfish, either directly or indirectly. Global variables include times series of anomalies in the Northwest Atlantic Oscillation (NAO) (Jones et al. 1997, Hurrell 1995, *http://www.cru.uea.ac.uk/cru*) and the position of the north wall of the Gulf Stream (*http://web.pml.ac.uk/gulfstream*). Regional sea surface temperature time series for the Northeast Continental Shelf, derived from the extended reconstruction sea surface temperature (ERSST) dataset of monthly mean values computed from the International Comprehensive Ocean Atmosphere Data Set (ICOADS) were provided by Friedland and Hare (2007). Chorophyll *a* (mg/m^3) time series (1997-2007) and primary productivity ($mgC/m^2/day$) time series (1998-2006), obtained from SeaWifs were provided by Friedland (pers.comm.)

Additional Data Series

Abundance of copepods and other common zooplankton taxa on Georges Bank during 1977-2004) (Kane 2007) and food habits data time series for several stocks (Jason Link, pers . comm.) were derived from NEFSC data collected on spring and autumn research bottom trawl surveys.

Results

Qualitative results

All of the figures of Z-scores and loess smooths , plots of proportion mature at age maturity, and VR plots are presented in the WP 2.1 Part II for all 20 stocks.

A qualitative review of the Z-score plots shows that mean length and mean weight generally trend in the same direction indicating that condition as not changed for any of these species over the time series (PartII. Fig. 2.1A1-Y1).

Six stocks show no particular trend in either mean length or mean weight in the more recent years:
Yellowtail flounder in GM-CC (PartII. Fig. 2.1.E1 and SNE (PartII. Fig. 2.1.D1), winter flounder in GM (PartII. Fig. 2.1.I1) and SNE (PartII. Fig. 2.1.J1), fluke (PartII. Fig. 2.1.V1 and mackerel (PartII. Fig. 2.1.X1).

Only two stocks show an increasing trend in mean length and mean weight in the most recent, 3 to 5 years: witch flounder (PartII. Fig. 2.1.G1) and adult silver hake(PartII. Fig.2.1.Y1).

The remaining 12 stocks show a recent decline in mean length and mean weight at age either within the last 3-5 years or for more than a decade in some cases, such as GB cod (Part II. Fig. 2.1.A1), GB haddock (Part II. Fig. 2.1.B1), white hake (Part II. Fig. 2.1.L1), Pollock (Part II. Fig. 2.1.M1), redfish (PartII. Fig. 2.1.N1), GM haddock (Part II. Fig. 2.1.R1), butterfish (Part II. Fig. 2.1.U1). One of the strongest declines was in the mean weight at age of American plaice (Part II. Fig. 2.1.H1).

The Visual Reports are a qualitative means of detecting year and year-class effects as well as potential density dependent effects on growth. All stocks exhibit year effects and these appear more pronounced for the flatfish stocks than for the gadids. Year class effects are more easily detected in the density plots rather than in mean length and weight, e.g. the 1963 haddock year class (Part II. Fig. 2.1.B2) and the 1971 GM cod year class (Part II. Fig. 2.1. F2).

Results suggest that some species may have ‘density dependent’ growth with faster growth during periods of low density and slower growth during periods of high density. In particular, Georges Bank haddock (Part II.Fig. 2.1.B3) show slow growth during the mid-1960s and early 2000s when stock density was relatively high. Witch flounder (Part II.Fig. 2.1.G3b-3c) and American plaice (Part II. Fig. 2.1.H3) show potential density dependent growth patterns during 1992-2005, however, the evidence is weaker for male American plaice than for female American plaice.

Female and male GB yellowtail flounder (Part II. Fig.2.1.C3b-c) show a reverse non-density dependent growth pattern during 1992-2005 with high values of mean length and mean weight when abundance is also high. GM winter flounder (Part II. Fig.2.1.I3b-c) shows a similar pattern, but not as strongly as the GB yellowtail flounder.

Mackerel (Part II. Fig.2.1. X3) exhibits density dependent growth at low density, however, during periods of high density mean weight is low, while mean length remains relatively constant. This suggests that competition or otherwise limited resources are affecting condition in mackerel and possibly silver hake.

Quintile plots of mean length ,weight and number at age were rearranged into different groupings as a way to detect similar patterns of response. Two ages were selected from each species that represented a juvenile, usually age 2, and an adult, usually an age greater than 5. Stocks were grouped by juveniles and adults by area (Fig. 2.1.3a-3c) and by species groups (Fig. 2.1.3d-f). Each stock was then grouped with the juvenile and adult quintiles adjacent to each other by area (Fig.2.1.3g-i).

Environmental time series are presented in Figures 2.1.4-2.1.9 and Fig. 2.1.15. The NAO anomalies (Fig. 2.1.4) and the North Wall of the Gulf Stream both show an increasing trend to positive anomalies from the mid-1960s to the mid-1990s. SST series show an increasing trend in the temperature difference of summer-winter (Fig. 2.1.5). Annual primary productivity (Fig. 2.1.9) shows a decline from 2000-2004, and then an increase in 2004-06.

Abundance anomalies of GB zooplankton (Fig. 2.1.10-12, and Fig. 2.1.16) show varying trends across species, however, the total abundance anomalies show a distinct pattern of negative anomalies prior to 1989 and generally positive values in the following years.

Food habits data ,presented as percent of body weight(Figures 2.1.13-2.1.14 and Fig. 2.1.17) do not show any strong trends.

Quantitative analysis

The randomization test and linear regression gave similar results for trend and probability level in both length and weight at age for all stocks (Fig. 2.1.1-2.1.2 and Table 2.1.2-2.1.5). In future analyses, however, only randomization tests will be used particularly for smaller data series, i.e. before and after implementation of closed areas. We will only present results from the randomization test in this paper.

Of the ten stocks reviewed, eight stocks had generally negative trends in both mean length and weight for the majority of ages (Table 2.1.2 - 2.1.5). Trends in mean length at age (Table 2.1.2) were significantly declining for the majority of ages for these stocks, with the exception of GM cod. Only the trend in age 0 mean length was significant, however, this age is not consistently well sampled in the survey, and is not applied in the GM cod assessment. Trends in mean weight at age (Table 2.1.4) were also significantly declining for the majority of ages for these stocks, with the exception of GM cod and GB haddock. Only one age had significant declining trends in mean weight for each of these stocks: age 0 GM cod, and age 4 GB haddock.

Silver hake had significantly decreasing trends in mean length and weight at age 1 and 2 and significantly increasing trends in mean length and weight at age 4 and age 5. Mackerel did not have any significant trends in mean length at age, but all ages were significantly declining for mean weight at age (Table 2.1.4).

GM winter flounder showed a non-significant increasing trend in mean length at age (Table 2.1.2) for most ages, however, the non-significant trends in mean weight at age (Table 2.1.4) were generally positive for younger ages and negative for the older ages. Yellowtail flounder was the only stock that had significantly increasing trends in mean length for the majority of ages. Yellowtail flounder also showed increasing trends in mean weight at age, but the trend was only significant for age 2 and age 3.

Two interesting patterns are apparent in these results for both mean length and mean weight at age. Trends in age 1 were not significant for any of the groundfish stocks (only silver hake), and most stocks showed the majority of ages over age 4 or 5 as having significant trends, with the exception of GM cod and winter flounder. For most of these stocks the age of full recruitment to the fishery is at or near age 4.

Exact binomial tests were significant (P=0.1) for estimated slopes of mean length at age for American plaice females and witch flounder males, and for estimated slopes of mean weight at age for GB cod, GB haddock, and females and males for both American plaice and witch flounder. These results indicate that all ages within a stock have the same trend in growth and that the similarity in trend among ages is not due to chance. Future analyses will address what mechanisms might generate declining trends in growth for all age groups within a particular stock.

Summary

Mean length, mean weight and maturity are biological parameters that integrate the lifetime effects of the environment experienced by an individual fish. As such, variations in these parameters are coarse measures of environmental change. While it is not possible to isolate the causal mechanisms and dangerous to posit facile explanations, the data herein provide compelling evidence of broad-scale changes in the bioenergetics of several fish species. The quintile plots allow for qualitative comparison of trends growth within and among species and for comparisons to environmental trends. On Georges Bank, positive recruit per spawner anomalies for cod, haddock and yellowtail flounder have been shown to be associated with positive anomalies of NAO (Brodziak and O'Brien 2005). In the North Sea, the abundance of copepods is associated with the NAO, and the North Wall of Gulf Stream (http://www.ecn.ac.uk/iccuk//indicators/32.htm). Similar analyzes will be conducted to determine if any significant trends can be detected between growth and environmental factors presented here. It must be emphasized that intensive investigations of relationships between some life stage of fish and an environmental factor are necessary but not sufficient to explain relationships at other life stages. Factors affecting growth of larval haddock may not be associated with abundance of age 1 fish. Close monitoring of growth rates, particularly among stocks and regions, provides an important tool for monitoring stock productivity and a wealth of testable hypotheses for quantifying environmental change.

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Table 2.1.1. Stocks reviewed for trends in mean length, mean weight, abundance and maturity at age.
(GARM=Groundfish Assesment Review Committee, SARC=Stock Assessment Review Committee, TRAC=Transboundary Resources Assessment Committee, GB=Georges Bank, GM= Gulf of Maine, SNE = Southern New England, MA= Mid-Atlantic.

Review Panel	**Assessment Model**	**GARM Letter**	**Stock**	**Years**	**Season** Length, Weight, Abundance	Maturity
GARM	VPA	A	GB Cod	1970-2007	Autumn	Spring
GARM	VPA	F	GM Cod	1970-2007	Autumn	Spring
GARM	VPA	B	GB Haddock	1963-2005	Autumn	Spring
GARM		R	GM Haddock	1963-2007	Autumn	Spring
GARM/TRAC	VPA	C	GB Yellowtail	1963-2007	Autumn	Spring
GARM	VPA	D	SNE Yellowtail Fld.	1970-2007	Autumn	Spring
GARM	VPA	E	GM-CC Yellowtail	1977-2007	Autumn	Spring
GARM	VPA	G	Witch flounder	1982-2007	Autumn	Spring
GARM	VPA	H	American plaice	1980-2007	Autumn	Spring
GARM	VPA	I	GM Winter fld	1976-2007	Autumn	Spring
GARM	VPA	J	SNE-MA Winter fld	1992-2006	Autumn	Spring
GARM	VPA	K	GB Winter fld	1982-2006	Autumn	Spring
GARM	Forward Proj.	L	GB-GM White hake	1982-2002	Autumn	Spring
GARM	INDEX	M	GB-GM Pollock	1970-2005	Autumn	Autumn
GARM	INDEX	N	GB-GM Redfish	1975-2006	Autumn	Spring
SARC	VPA		Fluke	1976-2007	Autumn	Autumn
TRAC	Forward Proj.		Herring	1968-2005	Autumn	Autumn
SARC	Forward Proj.		Mackerel	1973-2005	Autumn	Spring
SARC	INDEX		NGB Silver hake	1973-2004	Autumn	Spring
SARC	Forward Proj.		Butterfish	1982-2003	Autumn	Spring

Table 2.1.2 Probability values of randomization tests for linear trend in mean length at age for stocks from Georges Bank (GB), Gulf of Maine (GM),and Southern New England (SNE). Sexes are combined, unless noted otherwise. Shaded cells indicate a negative slope, no shading indicate positive slope. Significant values in bold (P < = 0.1).

		AGES										
		0	1	2	3	4	5	6	7	8	9	10
GB	Cod	0.8440	0.3140	0.1200	0.1400	**0.0700**	**0.0120**	**0.0020**	**0.0580**	0.3280	-	-
	Haddock	0.5260	0.9280	0.2740	0.1380	**0.0080**	**0.0100**	**0.0740**	**0.0280**	-	-	-
	Yellowtail -female	-	0.8320	**0.0220**	**0.0060**	**0.0860**	**0.0120**	0.5140	-	-	-	-
	Yellowtail-male	-	0.4260	**0.0080**	**0.0040**	**0.0300**	-	-	-	-	-	-
	Silver Hake (Northern)	0.9100	**0.0540**	**0.0080**	0.7440	**0.0020**	**0.0000**	-	-	-	-	-
GM	Cod	**0.0140**	0.7960	0.8880	0.9980	0.7400	0.2320	0.3980	0.7880	-	-	-
	Winter flounder -female	-	0.4580	0.4360	0.1000	**0.0840**	0.8640	0.4380	0.4940	-	-	-
	Winter flounder-male	-	0.9720	**0.0140**	**0.0820**	0.5180	0.3100	0.3080	-	-	-	-
	American *	-	0.2860	**0.0460**	**0.0240**	**0.0040**	**0.0020**	**0.0000**	**0.0040**	**0.0040**	**0.0260**	**0.0660**
	American plaice-male	-	0.9040	**0.0300**	**0.0020**	**0.0120**	**0.0040**	**0.0280**	0.2980	-	-	-
	Witch flounder-female	-	0.4100	0.3260	0.7220	0.1960	**0.0020**	**0.0000**	**0.0000**	**0.0420**	**0.0980**	0.1580
	Witch flou*	-	0.5240	0.3640	0.3260	**0.0940**	**0.0000**	**0.0000**	**0.0560**	**0.0780**	0.2860	-
SNE	Fluke-female	-	0.1600	0.6280	**0.0100**	**0.0000**	**0.0000**	**0.0080**	-	-	-	-
	Fluke-male	-	0.2180	0.4960	**0.0880**	**0.0000**	**0.0620**	-	-	-	-	-
	Mackerel	-	0.1480	0.6500	0.1440	0.8660	0.5760	0.3480	-	-	-	-

* Binomial Exact Test - Significant at P < = 0.10

Table 2.1.3 Slope of mean length-at-age over time for stocks from Georges Bank (GB), Gulf of Maine (GM), and Southern New England (SNE). Sexes are combined, unless noted otherwise.

		AGES										
		0	1	2	3	4	5	6	7	8	9	10
GB	Cod	-0.0032	-0.0157	-0.0249	-0.0238	-0.0289	-0.0397	-0.0548	-0.0380	-0.0237	-	-
	Haddock	0.0081	0.0009	-0.0141	-0.0190	-0.0334	-0.0306	-0.0226	-0.0301	-	-	-
	Yellowtail -female	-	-0.0180	0.1482	0.1668	0.1120	0.1625	0.0575	-	-	-	-
	Yellowtail-male	-	0.0533	0.1636	0.1743	0.1458	-	-	-	-	-	-
	Silver Hake (Northern)	0.0034	-0.0351	-0.0502	-0.0075	0.0617	0.0813	-	-	-	-	-
GM	Cod	0.0436	0.0045	-0.0008	-0.0001	-0.0064	0.0204	-0.0152	0.0054	-	-	-
	Winter flounder -female	-	-0.0581	0.0607	0.1129	0.1291	0.0177	-0.0765	0.0862	-	-	-
	Winter flounder-male	-	0.0034	0.1571	0.1187	0.0503	-0.0769	-0.1255	-	-	-	-
	American plaice-female	-	0.0802	-0.1528	-0.1581	-0.1916	-0.2012	-0.1978	-0.1969	-0.1674	-0.1918	-0.1776
	American plaice-male	-	0.0095	-0.1601	-0.1984	-0.1847	-0.1831	-0.1514	-0.1043	-	-	-
	Witch flounder-female	-	-0.0817	0.0838	0.0310	-0.0984	-0.2056	-0.2384	-0.2372	-0.1846	-0.1831	-0.1470
	Witch flounder-male	-	-0.0609	-0.0723	-0.0812	-0.1268	-0.2156	-0.1849	-0.1625	-0.2104	-0.1445	-
SNE	Fluke-female	-	0.0976	-0.0384	-0.1497	-0.1867	-0.2232	-0.1992	-	-	-	-
	Fluke-male	-	0.0832	0.0406	-0.1070	-0.1786	-0.1616	-	-	-	-	-
	Mackerel	-	0.0280	-0.0082	-0.0284	-0.0035	0.0103	0.0177	-	-	-	-

Table 2.1.4 Probability values of randomization tests for linear trend in mean weight at age for stocks from Georges Bank (GB), Gulf of Maine (GM),and Southern New England (SNE). Sexes are combined, unless noted otherwise. Shaded cells indicate a negative slope, no shading indicate positive slope. Significant values in bold (P < = 0.1).

		AGES										
		0	1	2	3	4	5	6	7	8	9	10
GB	Cod *	0.2900	0.2240	**0.0200**	**0.0400**	**0.0300**	**0.0060**	**0.0000**	**0.0140**	0.2200	-	-
	Haddock *	0.3980	0.7860	0.2360	0.1180	**0.0180**	0.1420	0.3940	**0.0360**	-	-	-
	Yellowtail -female	-	0.7060	**0.0420**	**0.0480**	0.3360	0.1860	0.8100	-	-	-	-
	Yellowtail-male	-	0.5320	**0.0260**	**0.0320**	0.1300	-	-	-	-	-	-
	Silver Hake (Northern)	0.7460	**0.0180**	**0.0020**	0.4300	**0.0000**	**0.0000**	-	-	-	-	-
GM	Cod	**0.0760**	0.5240	0.6120	0.9820	0.8980	0.1740	0.7940	0.4700	-	-	-
	Winter flounder -female	-	0.2380	0.8540	0.3340	0.2960	0.7100	0.1920	0.6620	-	-	-
	Winter flounder-male	-	0.7960	0.1080	0.4420	0.8180	0.2180	0.2260	-	-	-	-
	American *	-	0.9220	**0.0180**	**0.0180**	**0.0000**	**0.0000**	**0.0000**	**0.0000**	**0.0180**	**0.0120**	**0.0780**
	American *	-	0.4500	**0.0120**	**0.0000**	**0.0040**	**0.0000**	**0.0140**	0.2340	-	-	-
	Witch flou *	-	0.2020	0.1920	0.8320	0.1280	**0.0020**	**0.0000**	**0.0000**	**0.0180**	0.1000	0.1420
	Witch flou *	-	0.1440	0.1720	0.1100	**0.0460**	**0.0000**	**0.0060**	**0.0400**	**0.0640**	0.3000	-
SNE	Fluke-female	-	0.1340	0.7660	**0.0180**	**0.0020**	**0.0020**	**0.0080**	-	-	-	-
	Fluke-male	-	0.1960	0.3520	0.1280	**0.0020**	0.1960	-	-	-	-	-
	Mackerel	-	**0.0000**	**0.0260**	**0.0000**	**0.0000**	**0.0000**	**0.0000**	-	-	-	-

* Binomial Exact Test - Significant at P < = 0.10

Table 2.1.5 Slopes of mean weight-at-age over time for stocks from Georges Bank (GB), Gulf of Maine (GM), and Southern New England (SNE). Sexes are combined, unless noted otherwise.

		AGES										
		0	1	2	3	4	5	6	7	8	9	10
GB	Cod	-0.0172	-0.0206	-0.0339	-0.0317	-0.0346	-0.0425	-0.0649	-0.0457	-0.0309	-	-
	Haddock	0.0110	-0.0048	-0.0179	-0.0228	-0.0443	-0.0240	-0.0174	-0.0366	-	-	-
	Yellowtail -female	-	-0.0280	0.1215	0.1197	0.0659	0.0945	0.0221	-	-	-	-
	Yellowtail-male	-	0.0434	0.1356	0.1368	0.1080	-	-	-	-	-	-
	Silver Hake (Northern)	-0.0073	-0.0473	-0.0559	-0.0144	0.0610	0.0815	-	-	-	-	-
GM	Cod	0.0328	-0.0106	-0.0095	-0.0008	-0.0029	0.0222	-0.0043	0.0157	-	-	-
	Winter flounder -female	-	-0.0908	0.0094	0.0727	0.0832	-0.0354	-0.1081	0.0510	-	-	-
	Winter flounder-male	-	-0.0230	0.1129	0.0632	0.0179	-0.0984	-0.1450	-	-	-	-
	American plaice-female	-	0.0058	-0.1696	-0.1764	-0.2022	-0.2157	-0.2092	-0.1978	-0.1741	-0.2080	-0.1783
	American plaice-male	-	-0.0633	-0.1792	-0.2036	-0.2031	-0.2065	-0.1646	-0.1158	-	-	-
	Witch flounder-female	-	-0.1228	0.1087	0.0170	-0.1174	-0.2091	-0.2363	-0.2427	-0.1889	-0.1830	-0.1465
	Witch flounder-male	-	-0.1290	-0.1092	-0.1230	-0.1493	-0.2157	-0.1819	-0.1724	-0.2248	-0.1358	-
SNE	Fluke-female	-	0.1003	-0.0223	-0.1425	-0.1800	-0.2024	-0.1771	-	-	-	-
	Fluke-male	-	0.0881	0.0664	-0.0971	-0.1699	-0.1113	-	-	-	-	-
	Mackerel	-	0.0617	-0.0384	-0.0784	-0.0801	-0.0823	-0.0771	-	-	-	-

MEAN LENGTH AT AGE

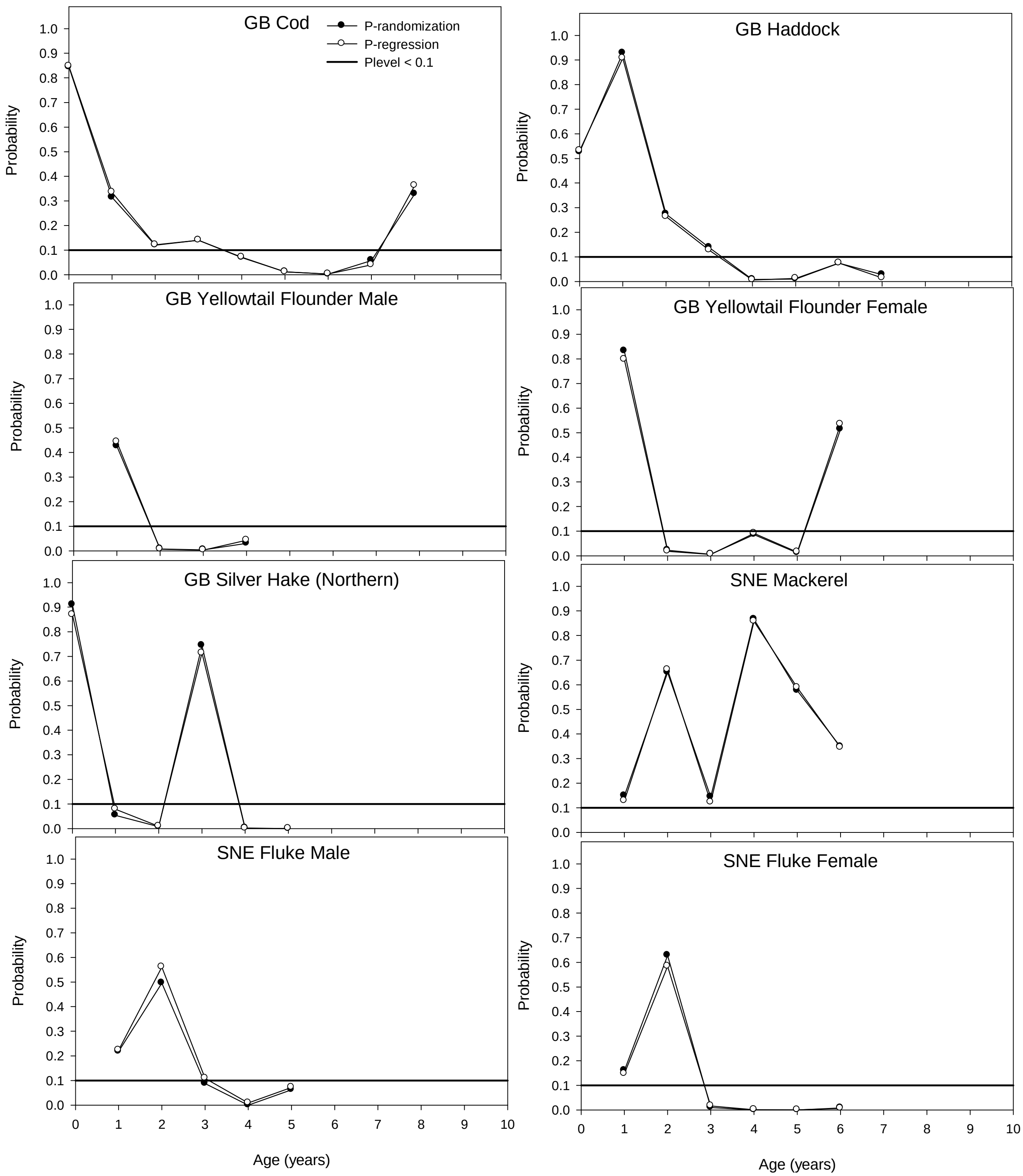

Figure 2.1.1. Probability values of randomization tests and linear regression at age for mean length at age for 10 stocks, with P <= 0.1.

MEAN LENGTH AT AGE

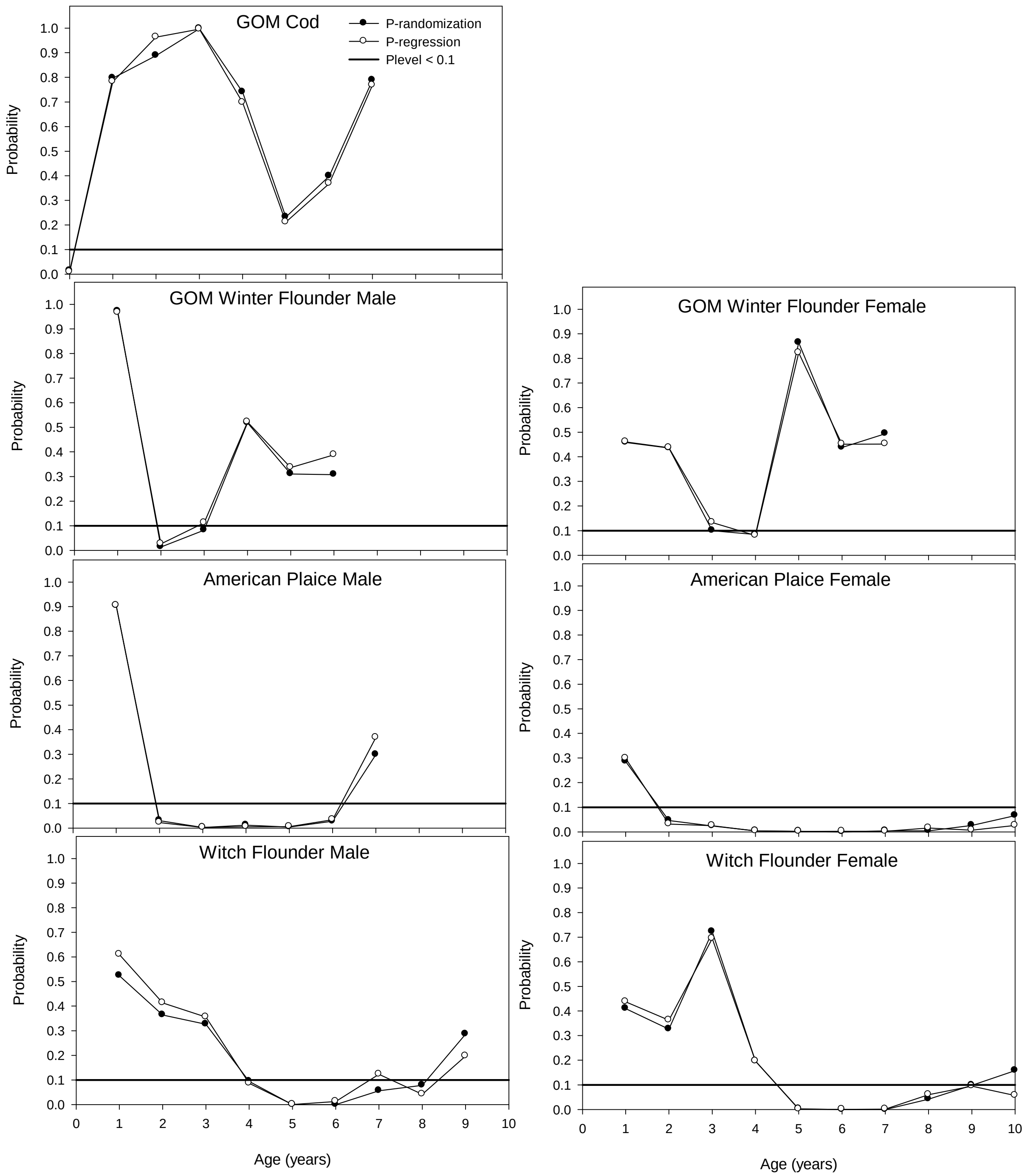

Figure 2.1.1 continued. Probability values of randomization tests and linear regression at age for mean length at age for 10 stocks, with P <= 0.1.

MEAN WEIGHT AT AGE

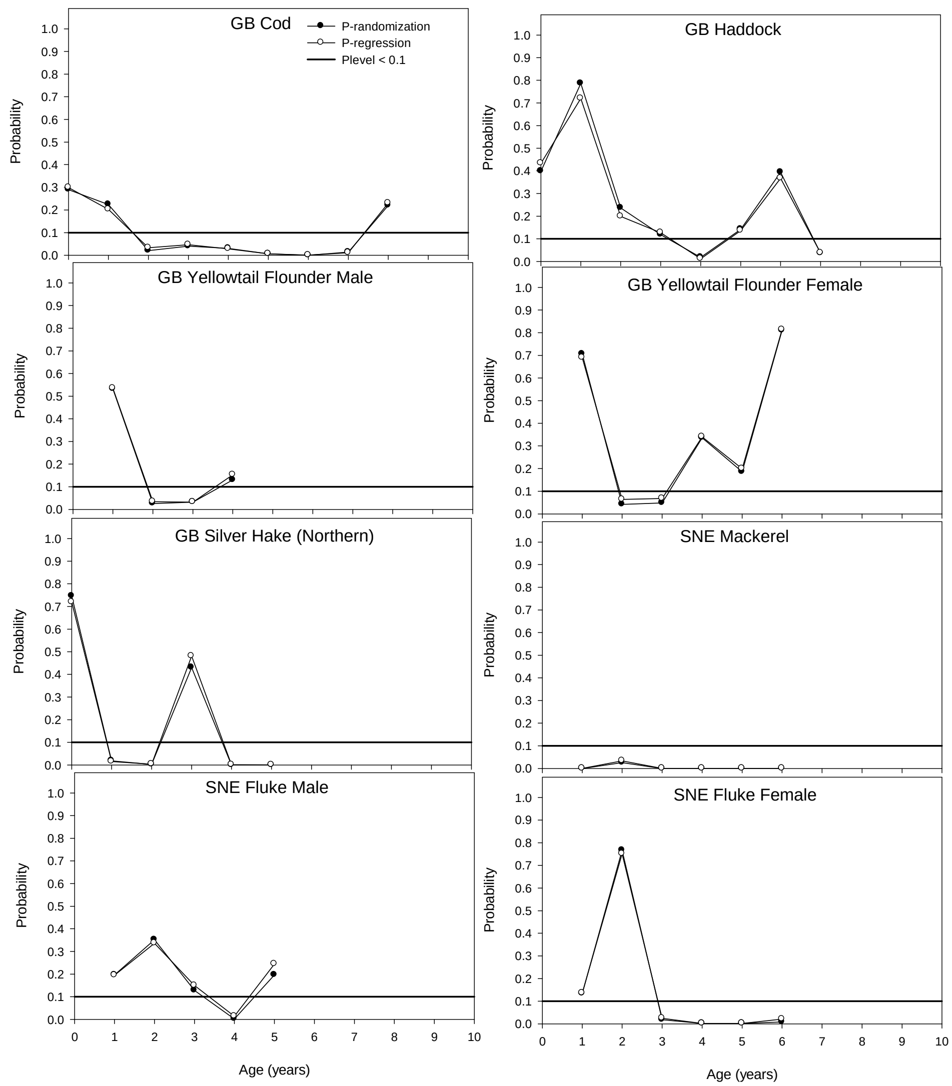

Figure 2.1.2. Probability values of randomization tests and linear regression at age for mean weight at age for 10 stocks, with P <= 0.1.

MEAN WEIGHT AT AGE

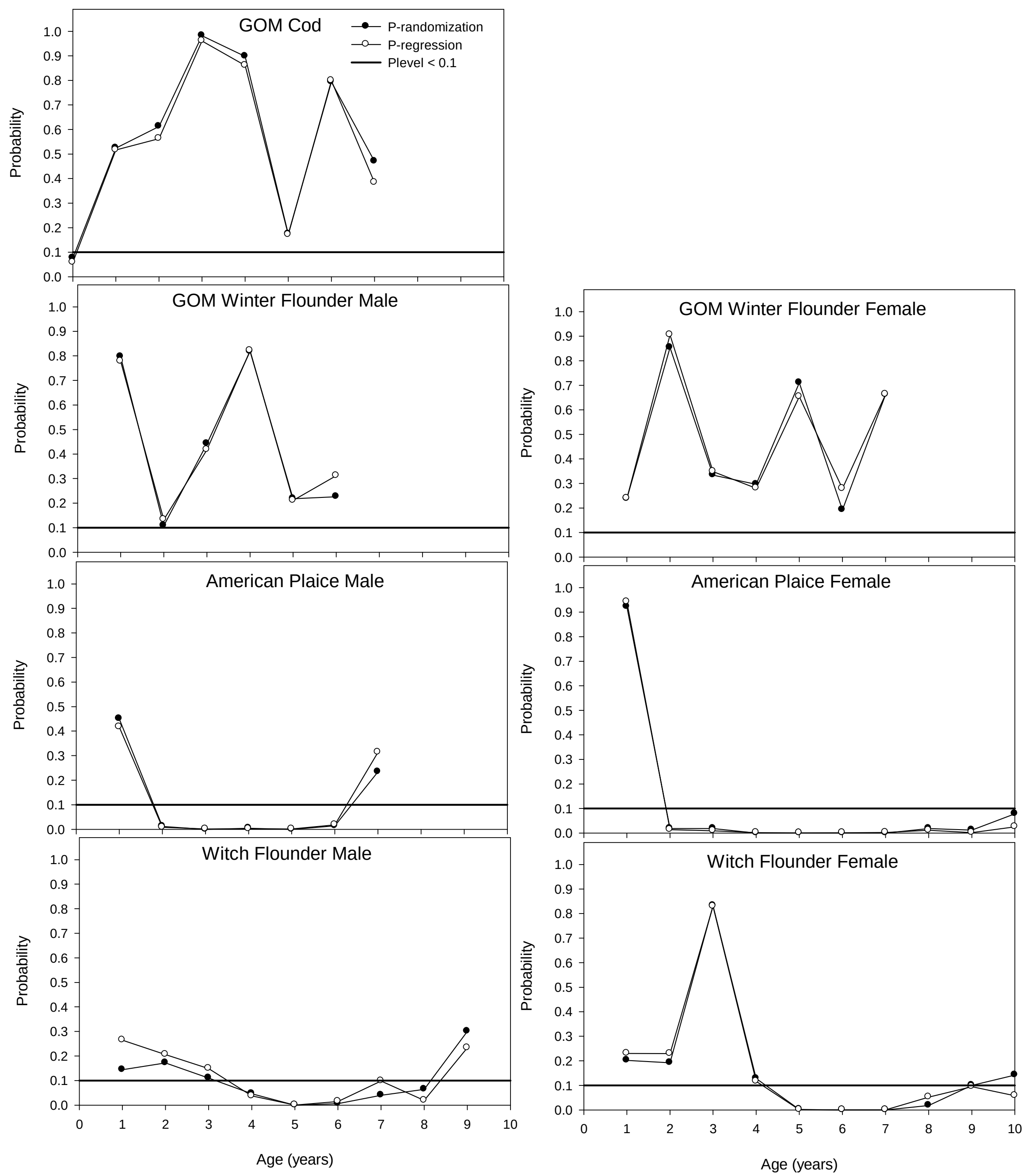

Figure 2.1.2 continued. Probability values of randomization tests and linear regression at age for mean weight at age for 10 stocks, with P <= 0.1.

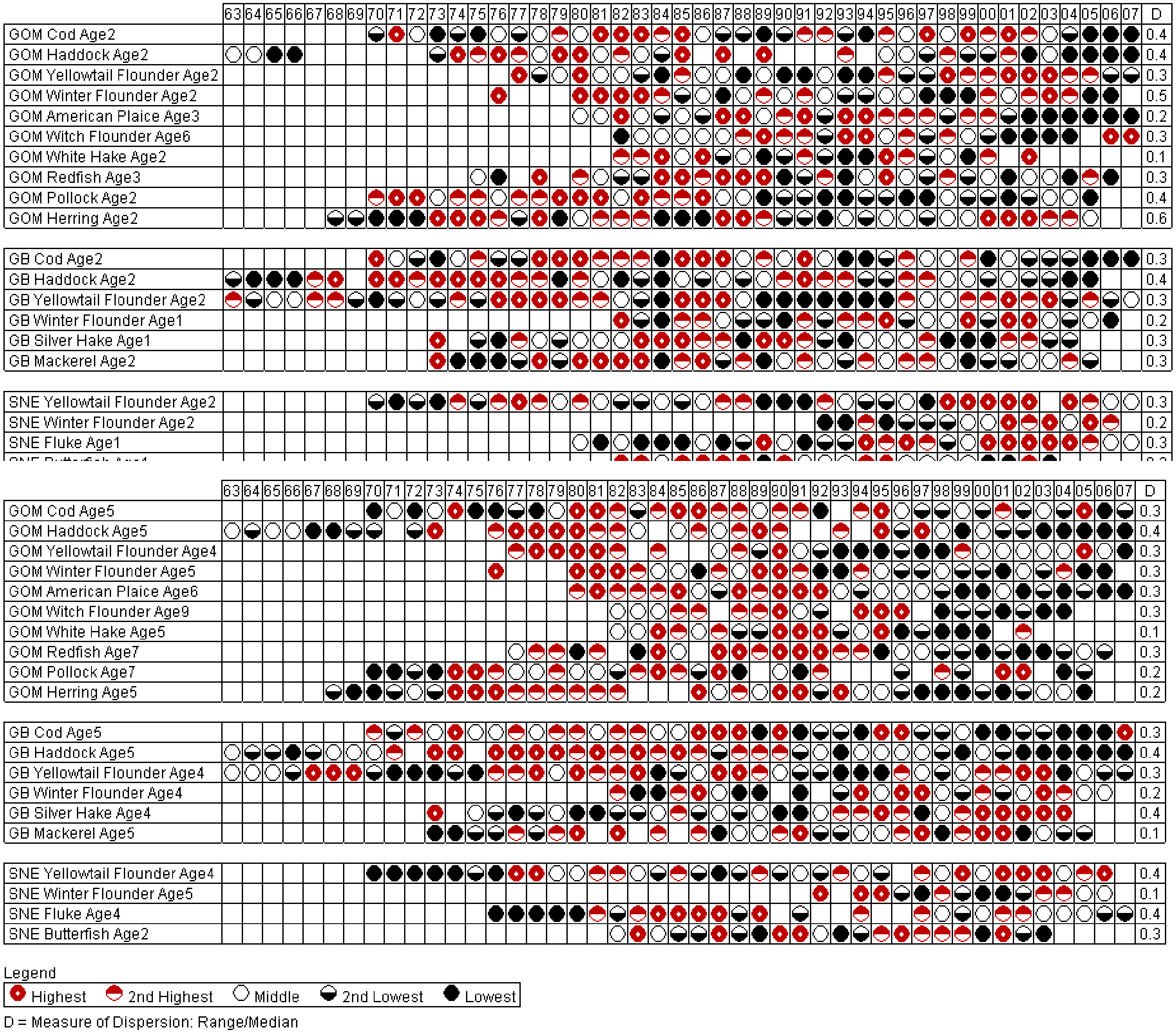

Figure 2.1.3a Quintiles of stratified **mean length** with dispersion estimates for selected groundfish grouped as juveniles and adults by area (GOM=Gulf of Maine, GB=Georges Bank, SNE = Southern New England.

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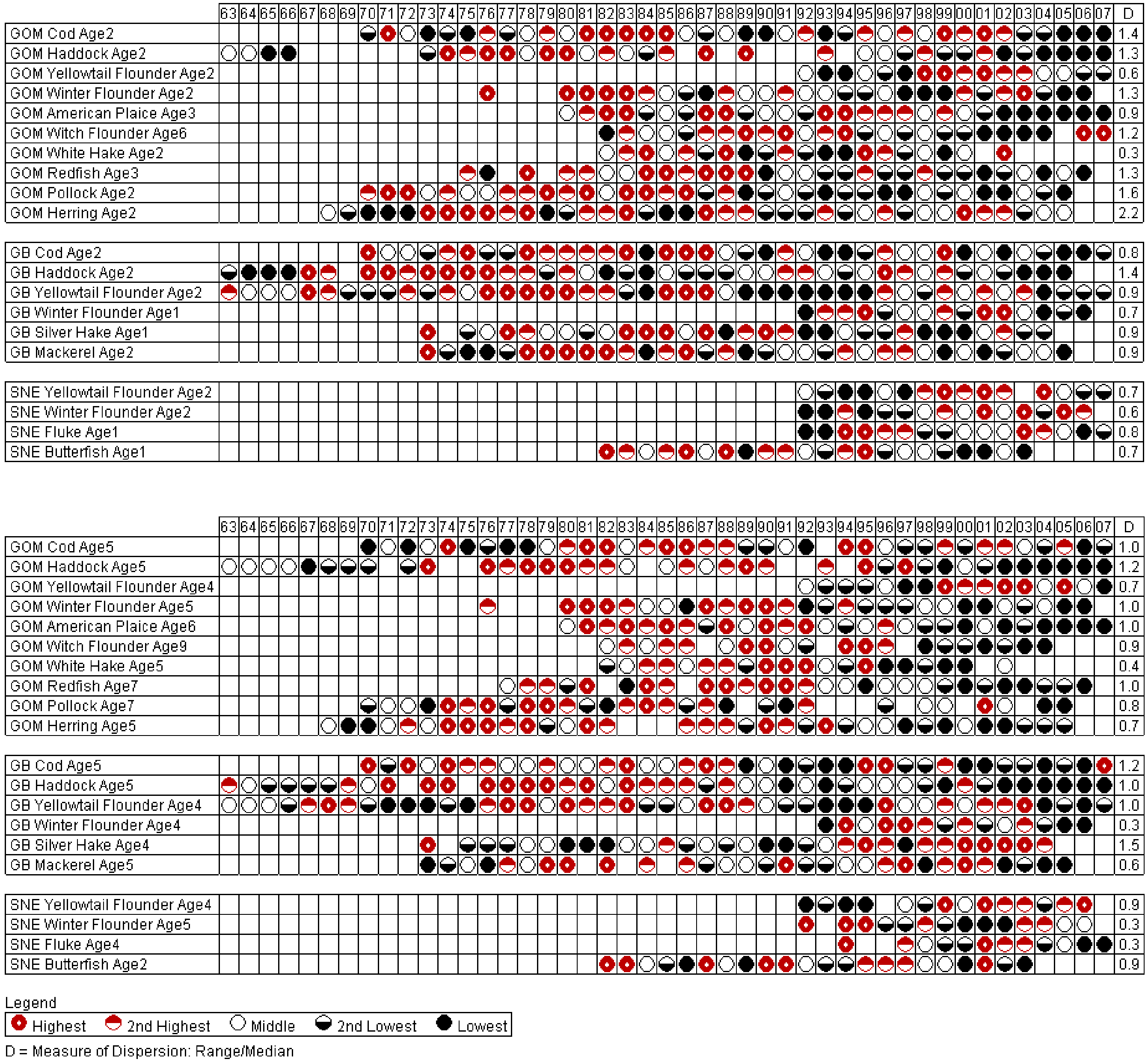

Figure 2.1.3b. Quintiles of stratified **mean weight** with dispersion estimates for selected groundfish grouped as juveniles and adults by area (GOM=Gulf of Maine, GB=Georges Bank, SNE = Southern New England).

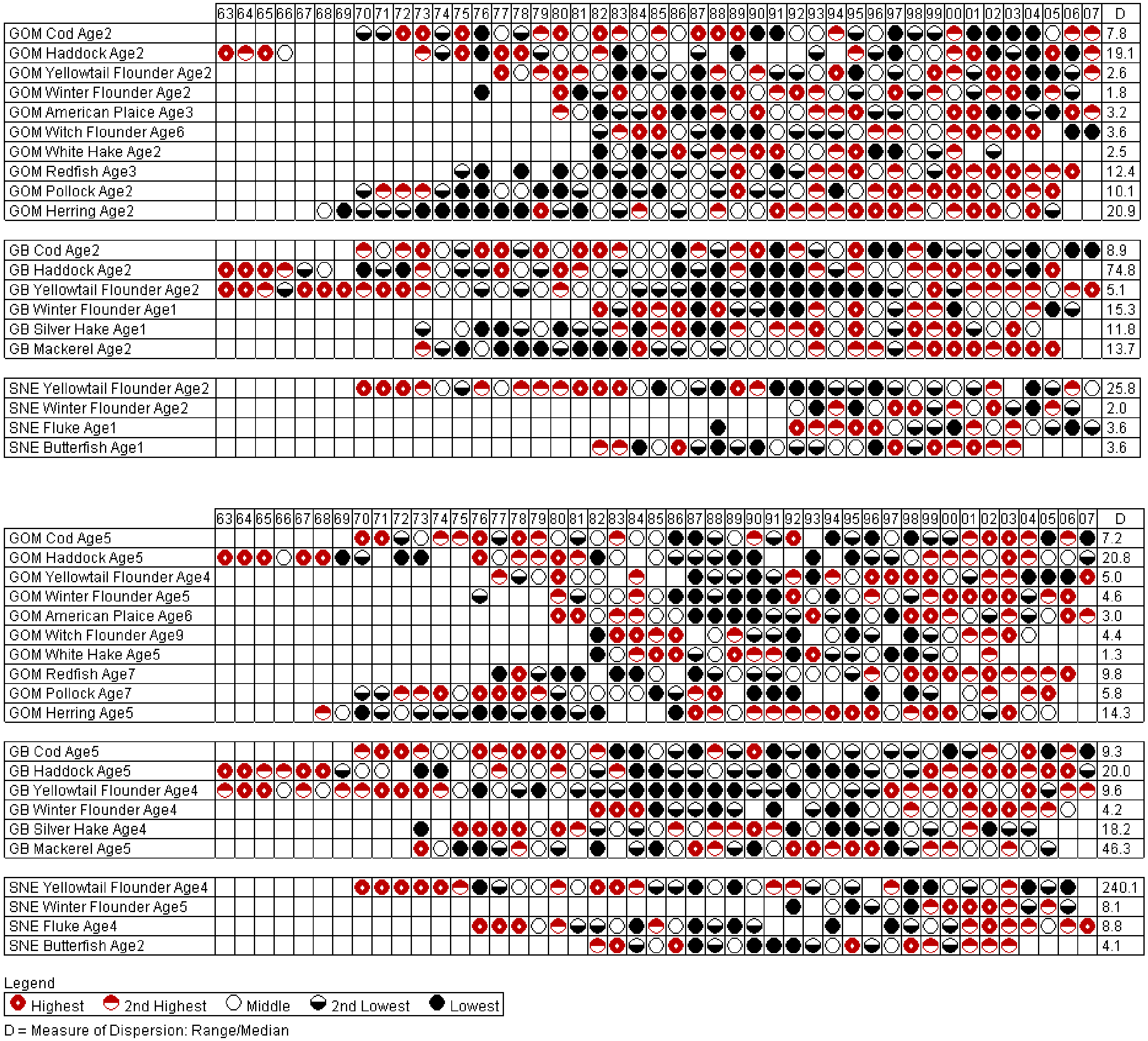

Figure 2.1.3c. Quintiles of stratified **mean number** with dispersion estimates for selected groundfish grouped as juveniles and adults by area (GOM=Gulf of Maine, GB=Georges Bank, SNE = Southern New England).

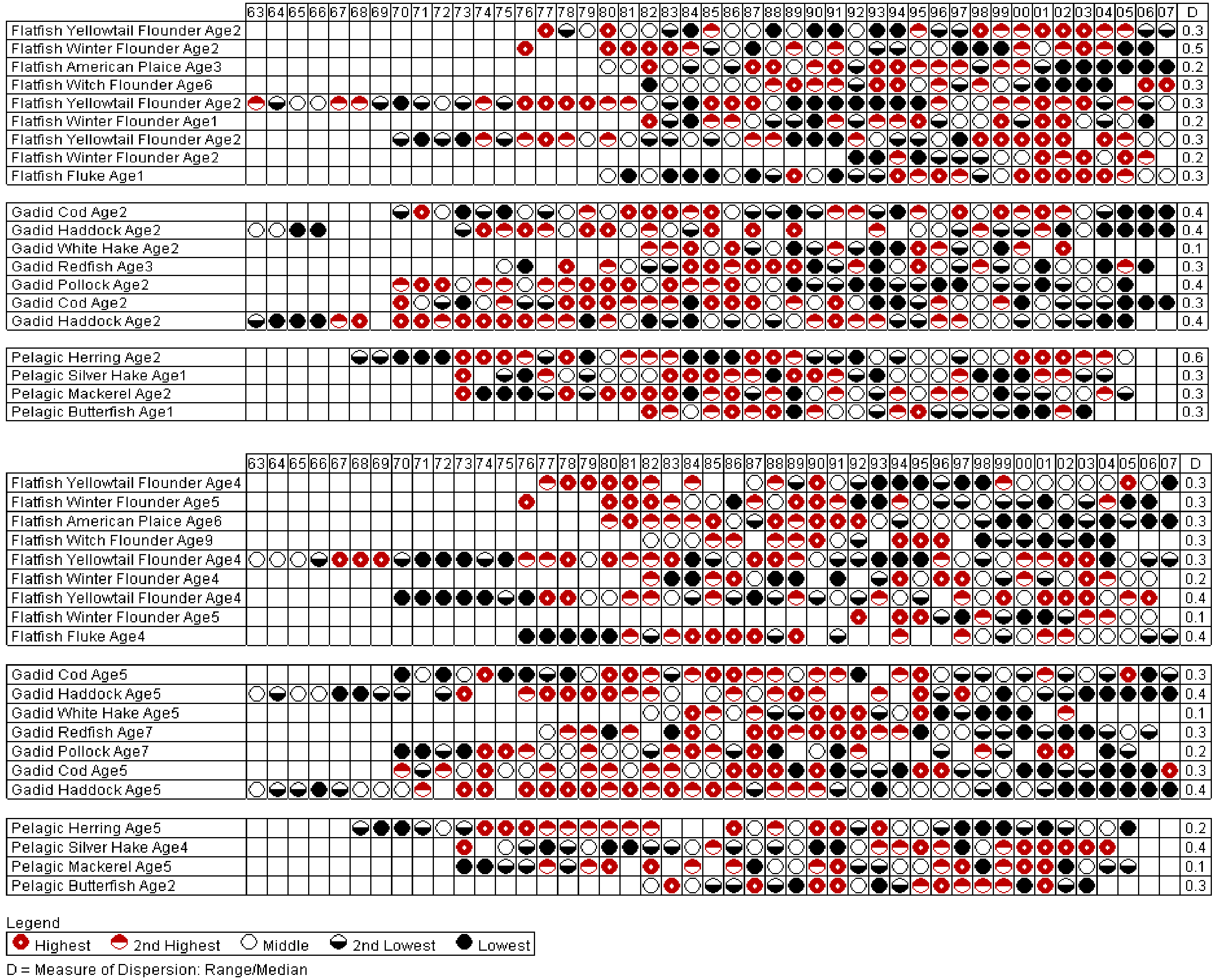

Figure 2.1.3d. Quintiles of stratified **mean length** with dispersion estimates for selected groundfish grouped as juveniles and adults by species groups.

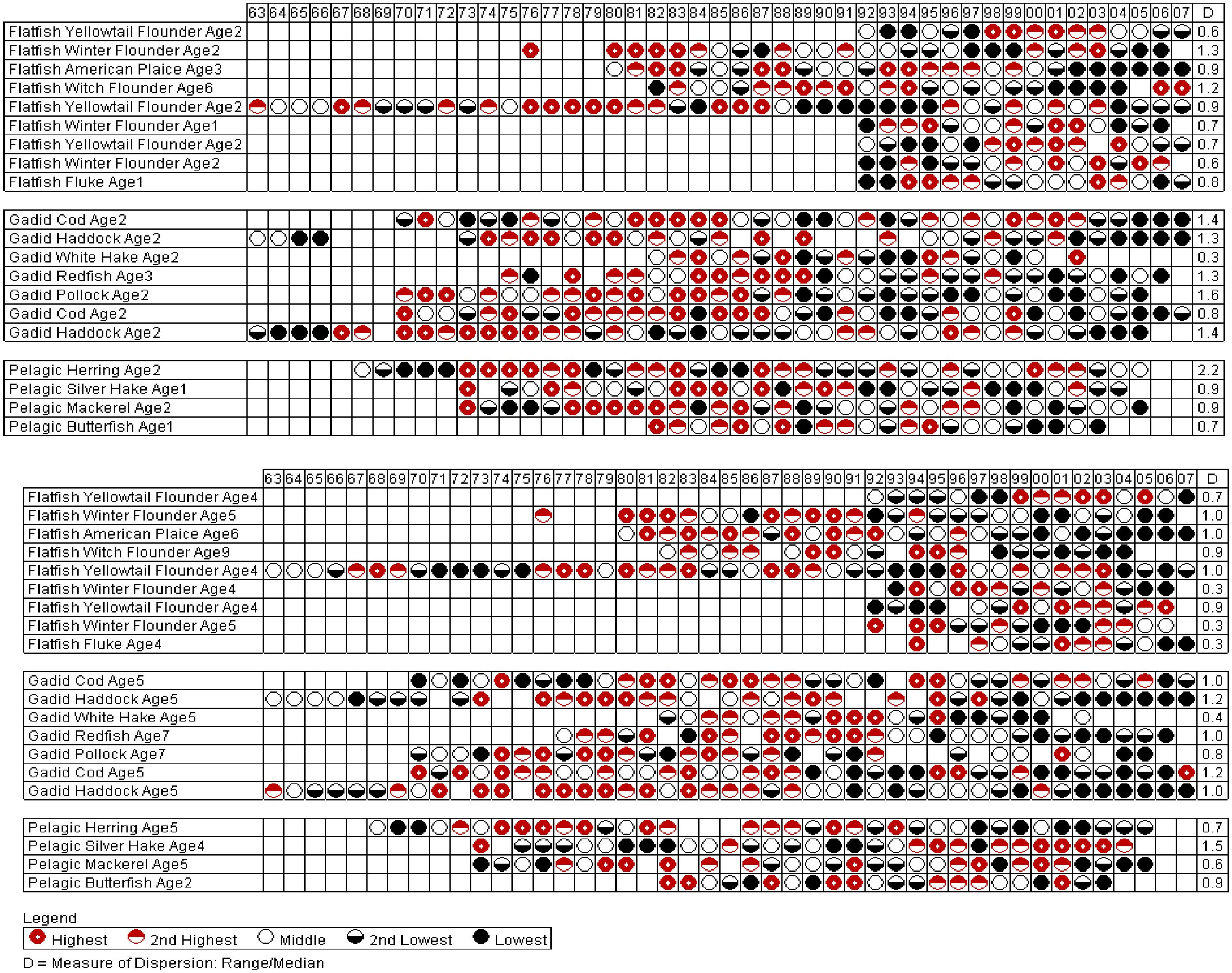

Figure 2.1.3e. Quintiles of stratified **mean weight** with dispersion estimates for selected groundfish grouped as juveniles and adults by species groups.

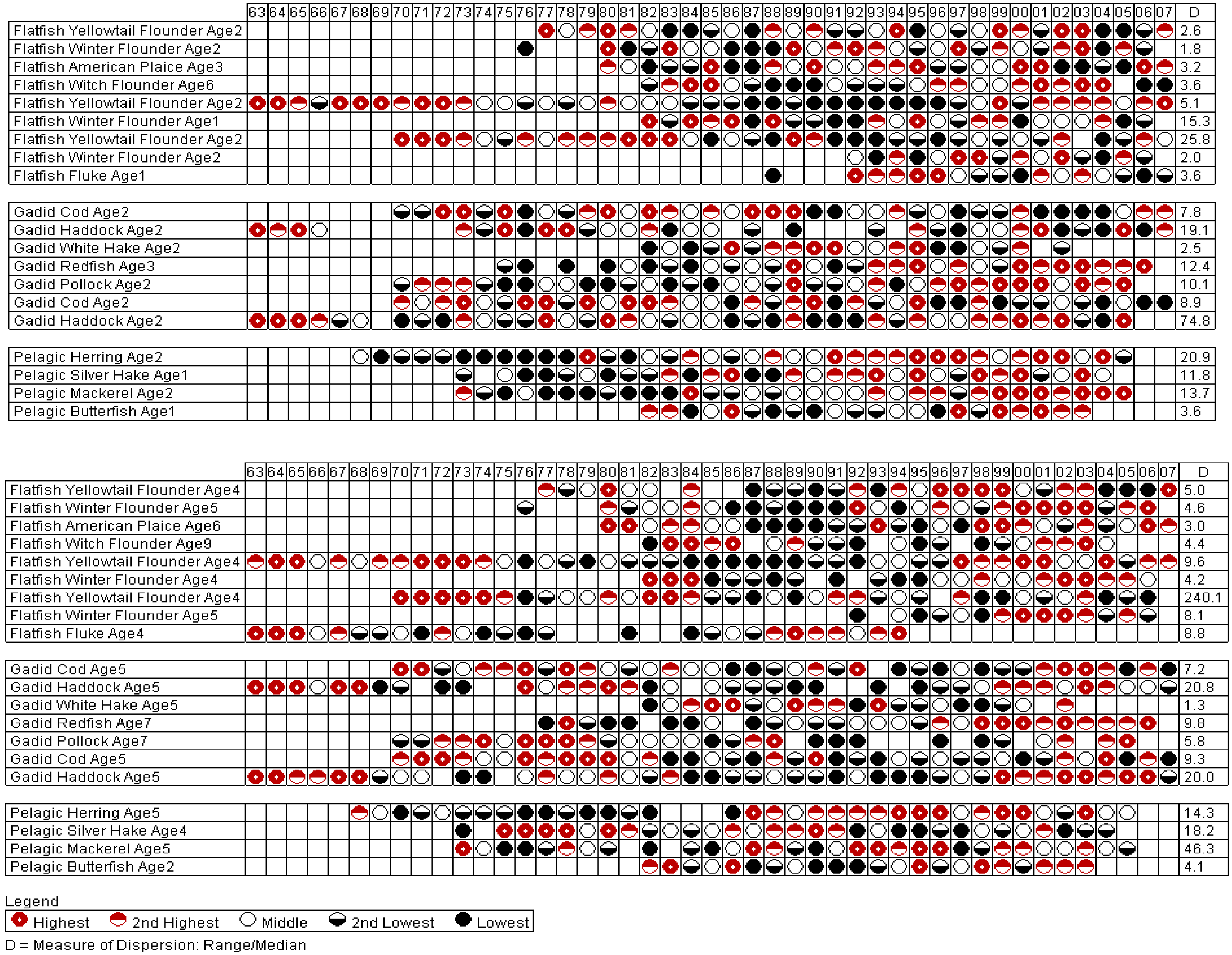

Figure 2.1.3f. Quintiles of stratified **mean number** with dispersion estimates for selected groundfish grouped as juveniles and adults by species groups.

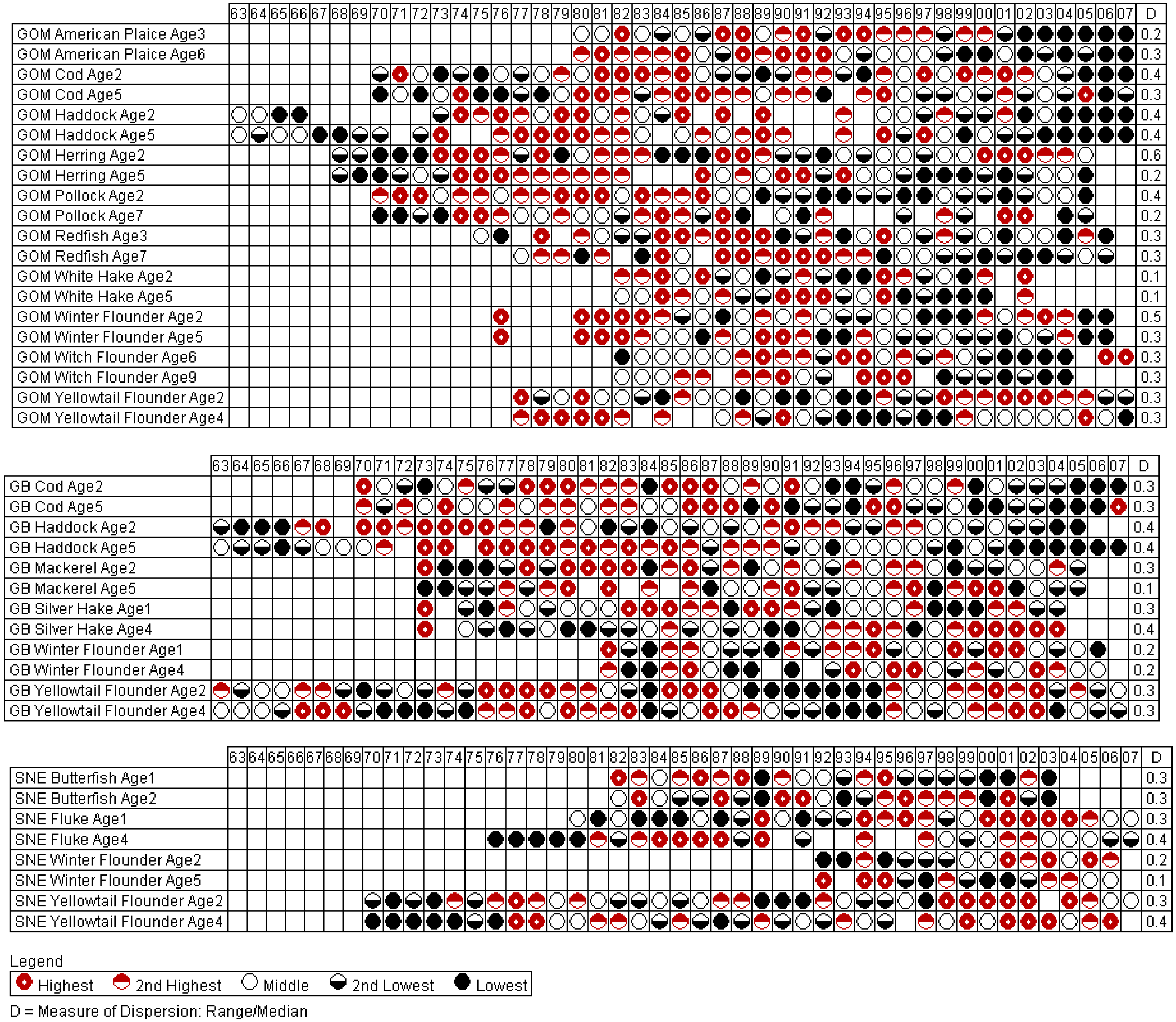

Figure 2.1.3g. Quintiles of stratified **mean length** with dispersion estimates for selected groundfish grouped as juveniles and adults by area (GOM=Gulf of Maine, GB=Georges Bank, SNE = Southern New England).

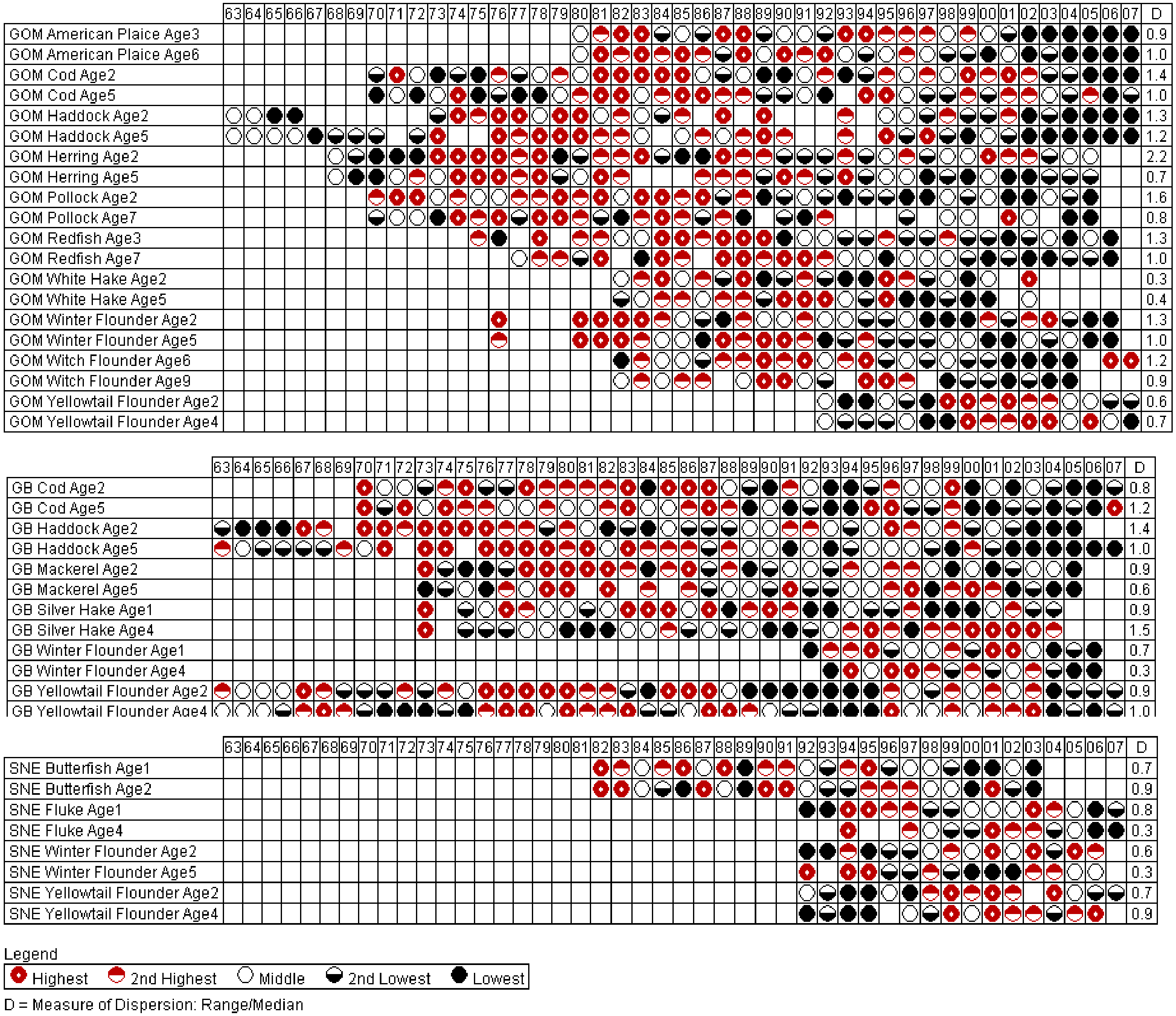

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Figure 2.1.3h. Quintiles of stratified **mean weight** with dispersion estimates for selected groundfish grouped as juveniles and adults by area (GOM=Gulf of Maine, GB=Georges Bank, SNE = Southern New England).

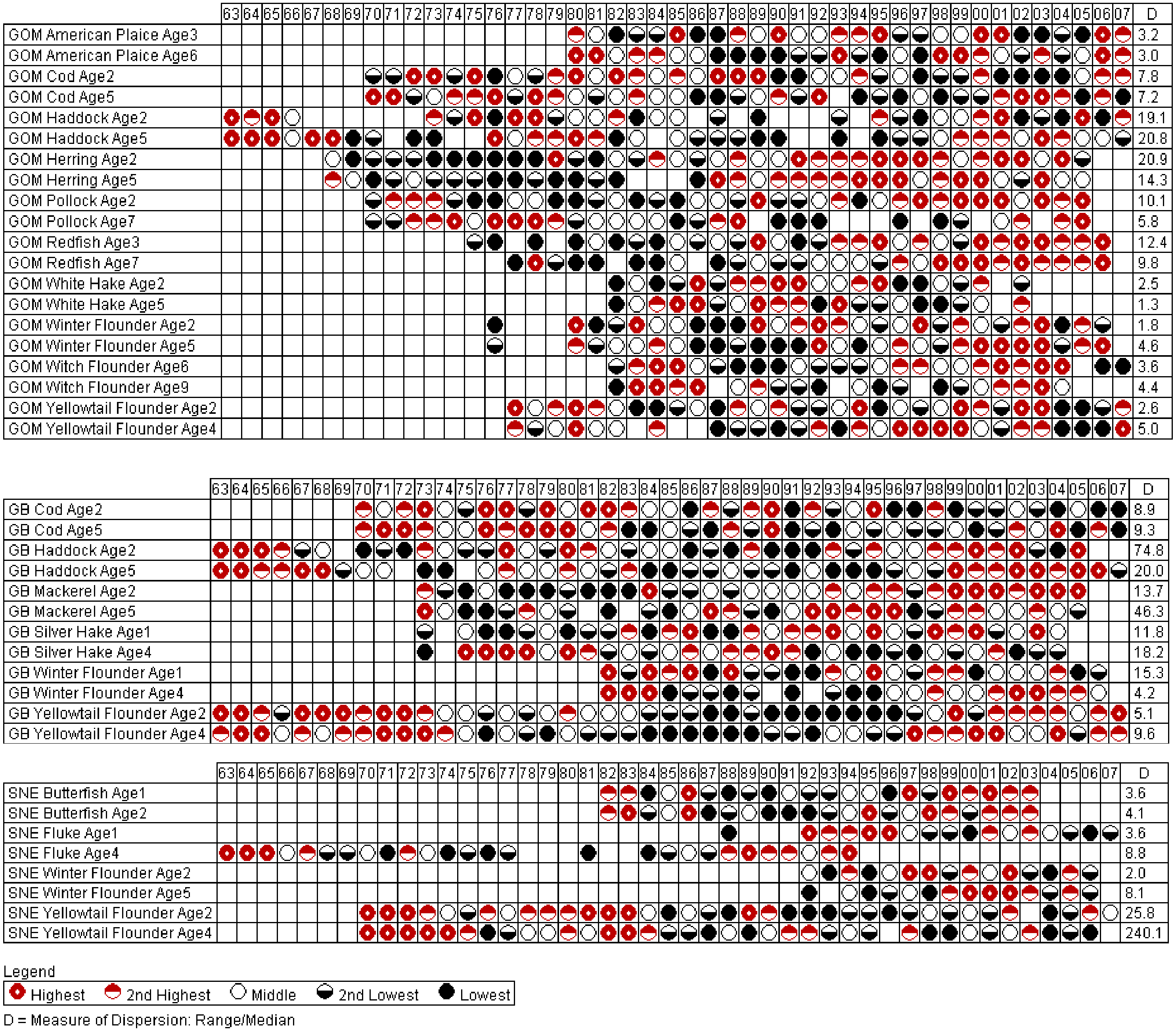


Figure 2.1.3i. Quintiles of stratified **mean number** with dispersion estimates for selected groundfish grouped as juveniles and adults by area (GOM=Gulf of Maine, GB=Georges Bank, SNE = Southern New England).

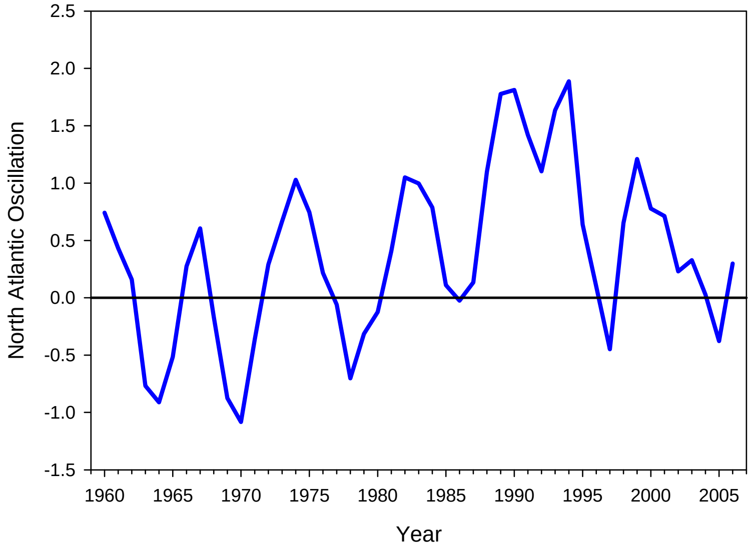


Figure 2.1.4 North Atlantic Osciallation (NAO) , 3-year moving average from 1960-2006.

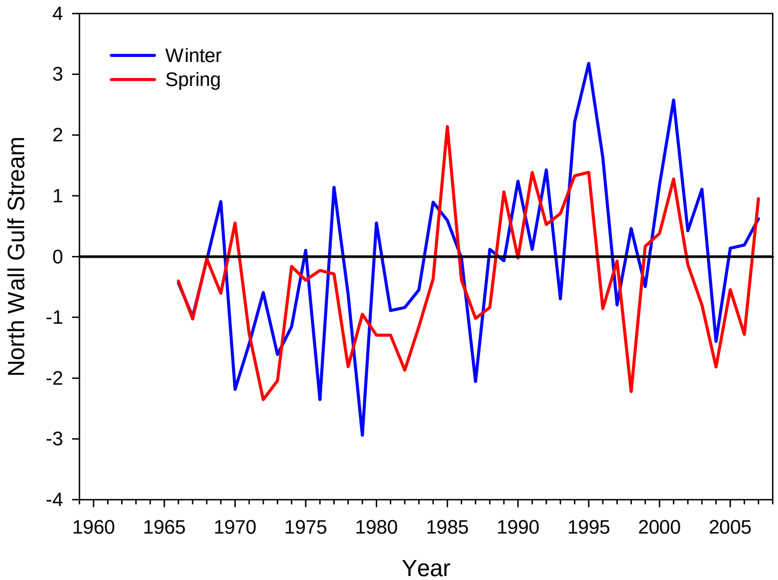


Figure 2.1.5. North Wall Gulf Stream, winter and spring from 1966-2007.

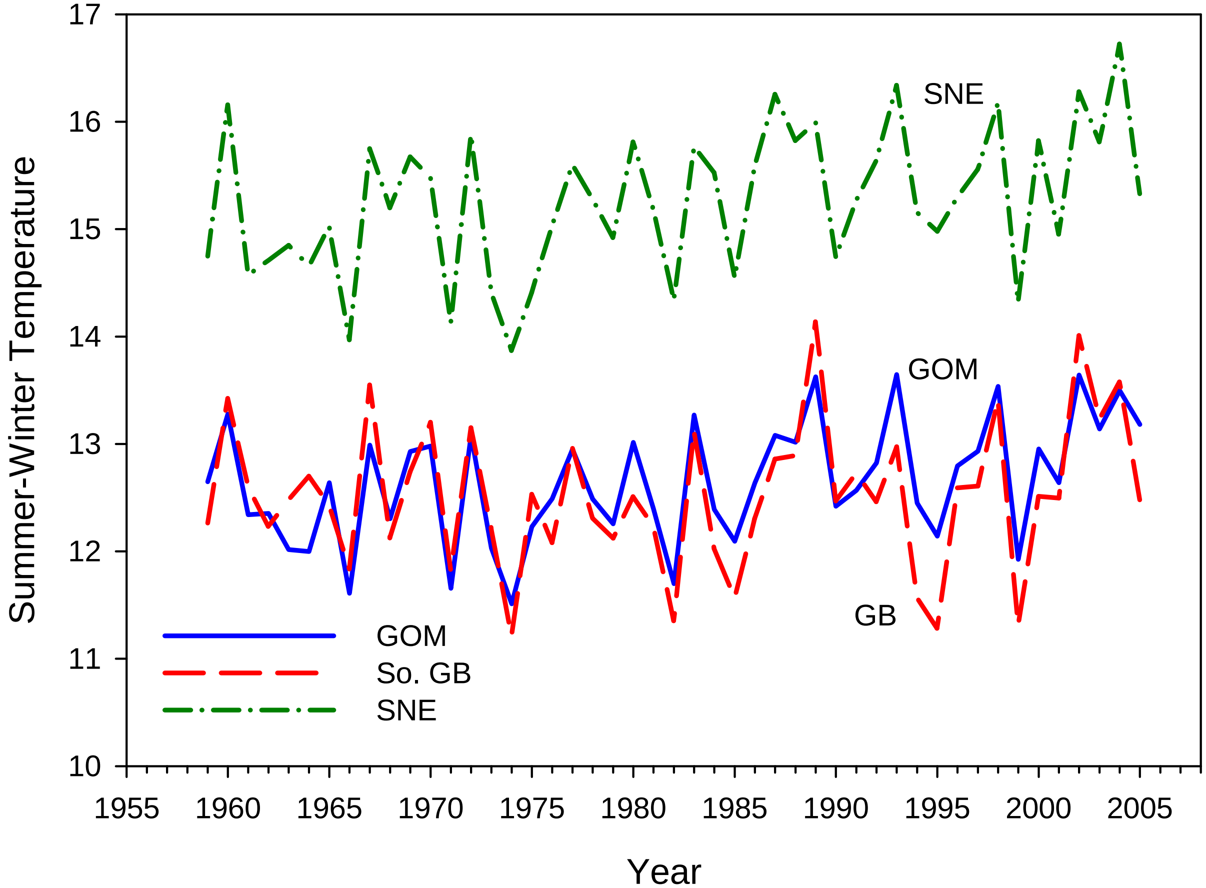


Figure 2.1.5. Summer-Winter temperatures for Gulf of Maine (GOM), Southern Georges Bank (So. GB), and Southern New England (SNE) from 1960-2006.

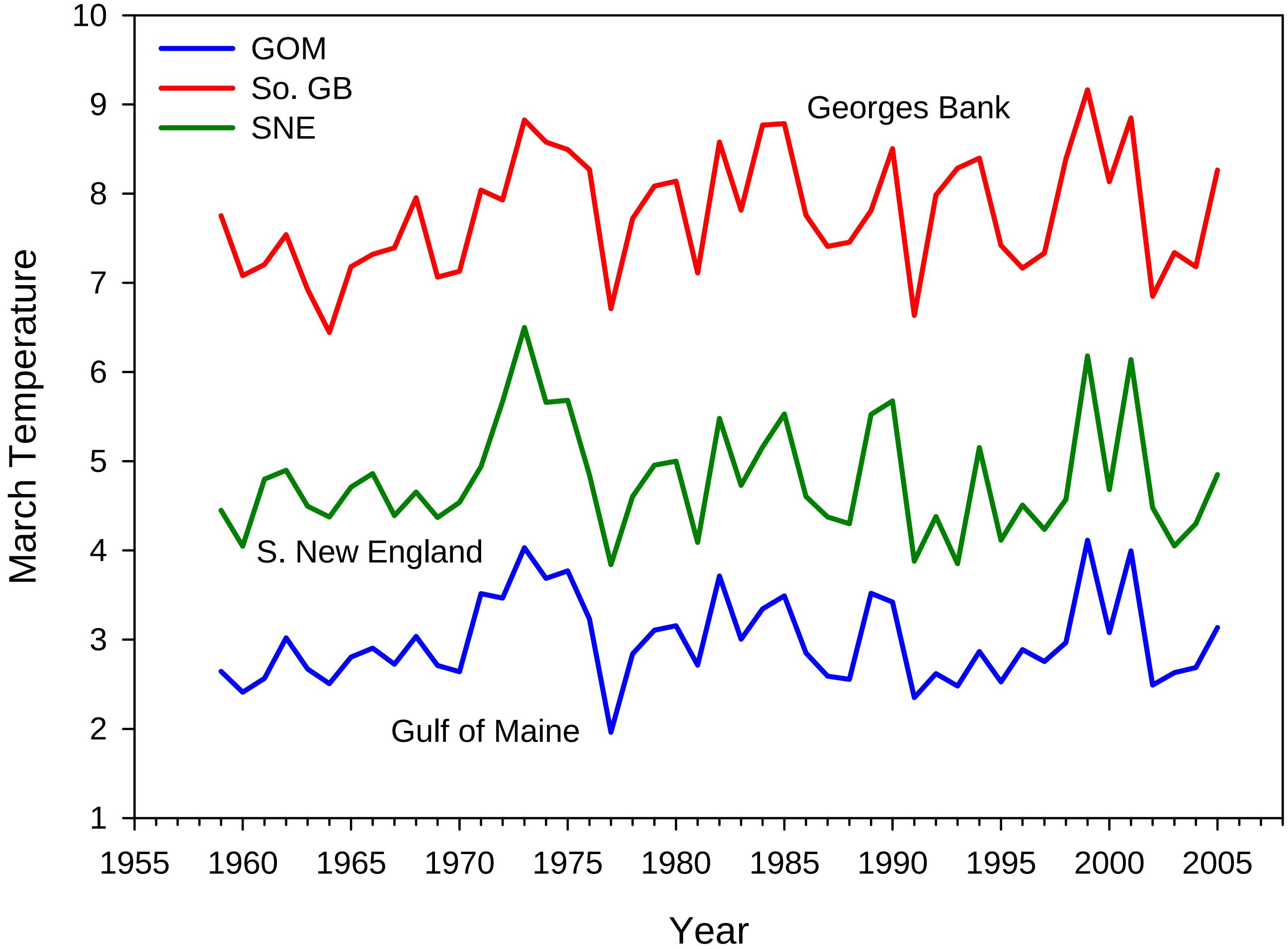


Figure 2.1.6 March temperatures for Gulf of Maine (GOM), Southern Georges Bank (So. GB), and Southern New England (SNE) from 1960-2006.

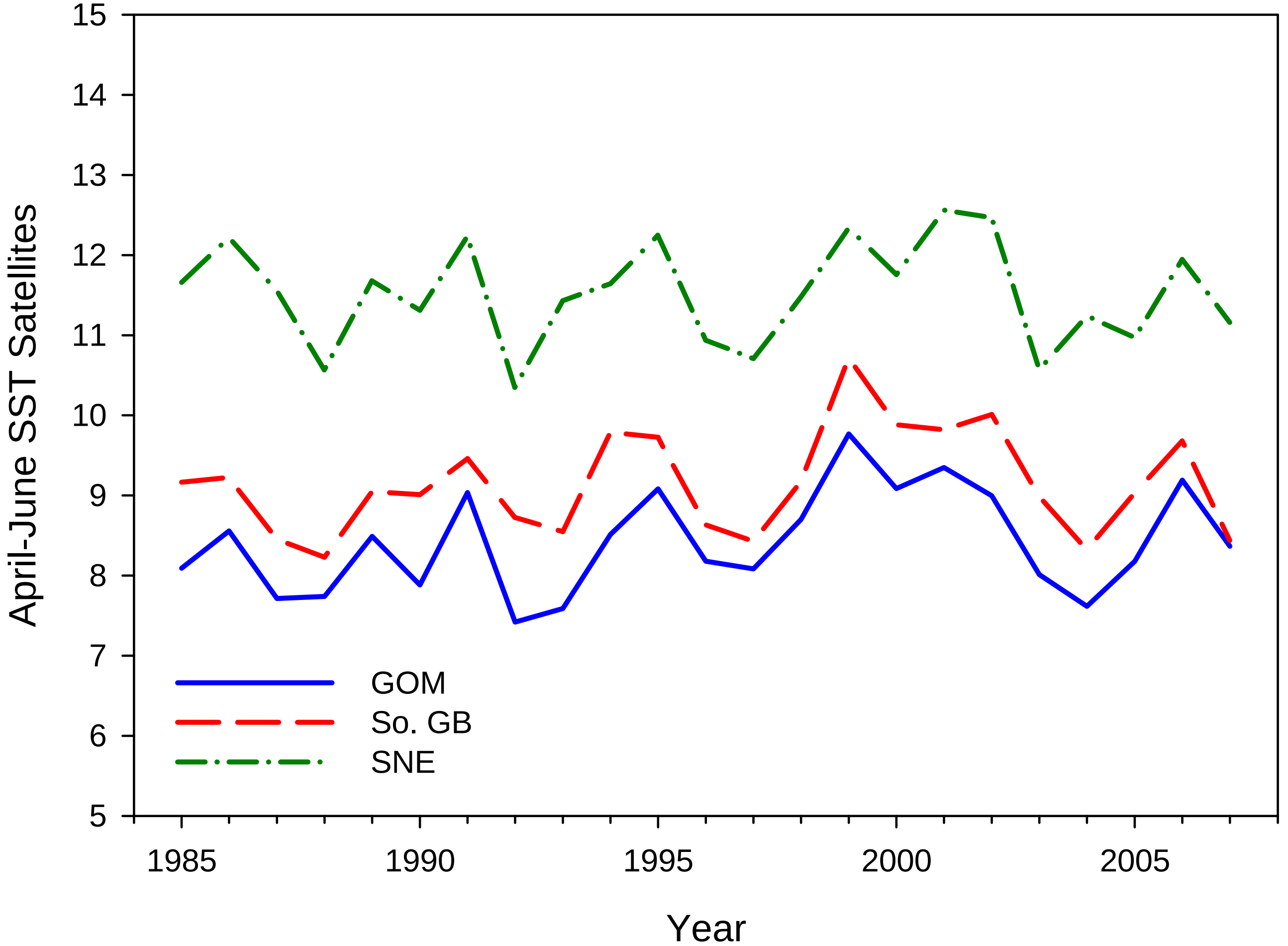


Figure 2.1.7. April-June SST satellites for Gulf of Maine (GOM), Southern Georges Bank (So. GB), and Southern New England (SNE) from 1985-2007.

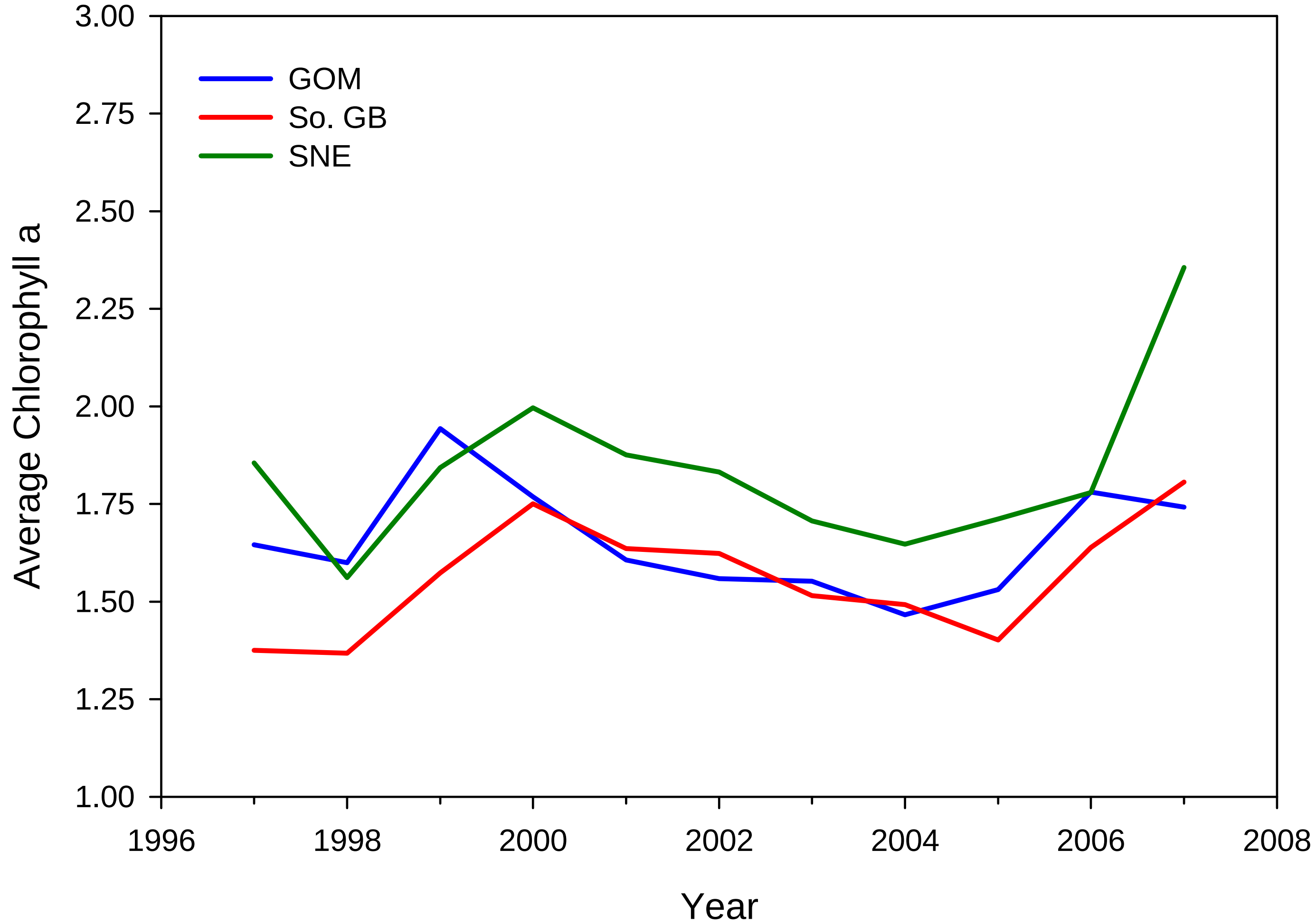


Figure 2.1.8 Average chlorophyll a (mg/m**3) for Gulf of Maine (GOM), Southern Georges Bank (So. GB), and Southern New England (SNE) from 1985-2007.

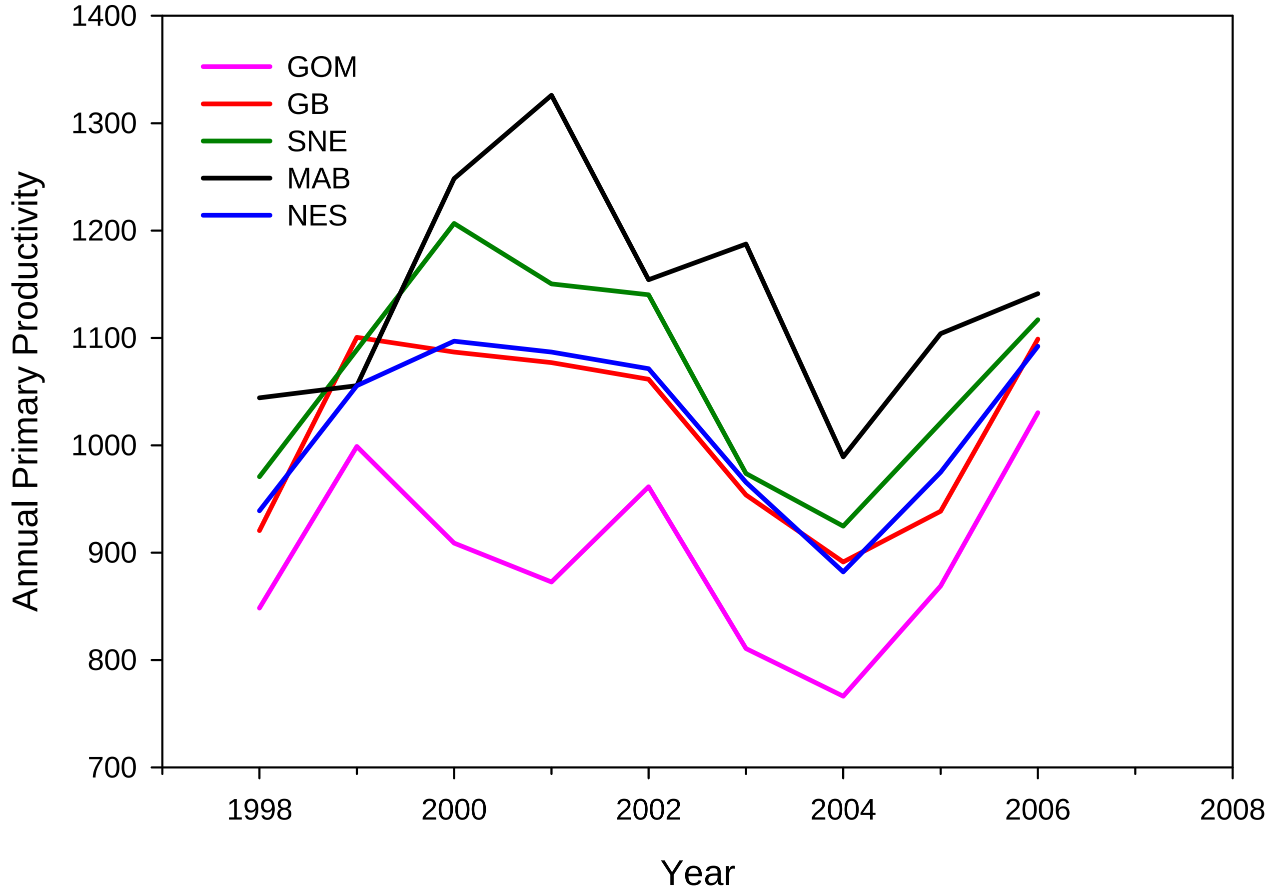


Figure 2.1.9 Annual primary productivity (mg C/m**2 /day for Gulf of Maine (GOM), Georges Bank (GB), Southern New England (SNE), Mid-Atlantic Bight (MAB), and Northeast Shelf (NES) during 1998-2006.

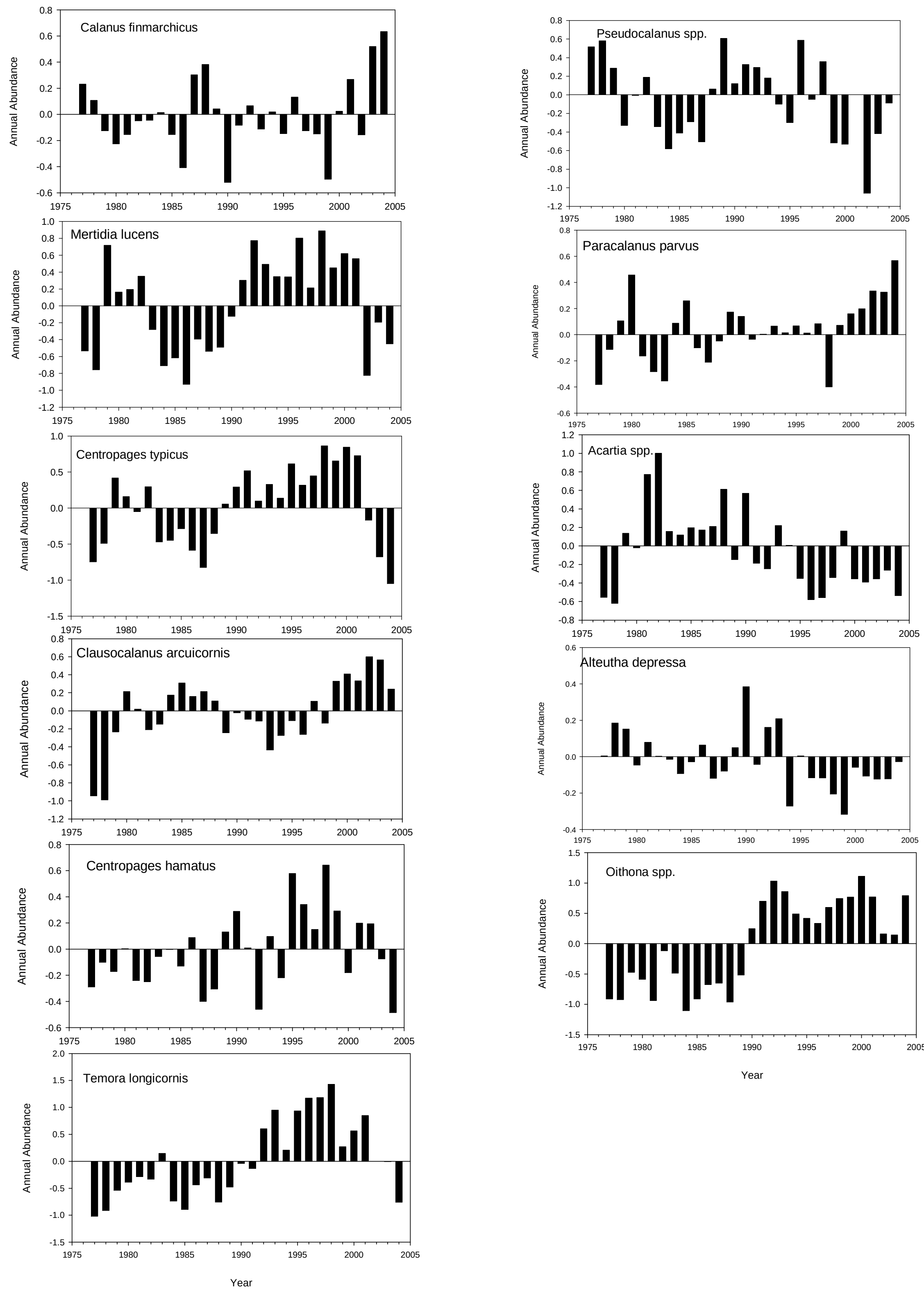


Figure 2.1.10. Annual abundance anomalies of common zooplankton taxa on Georges Bank from 1977-2004.

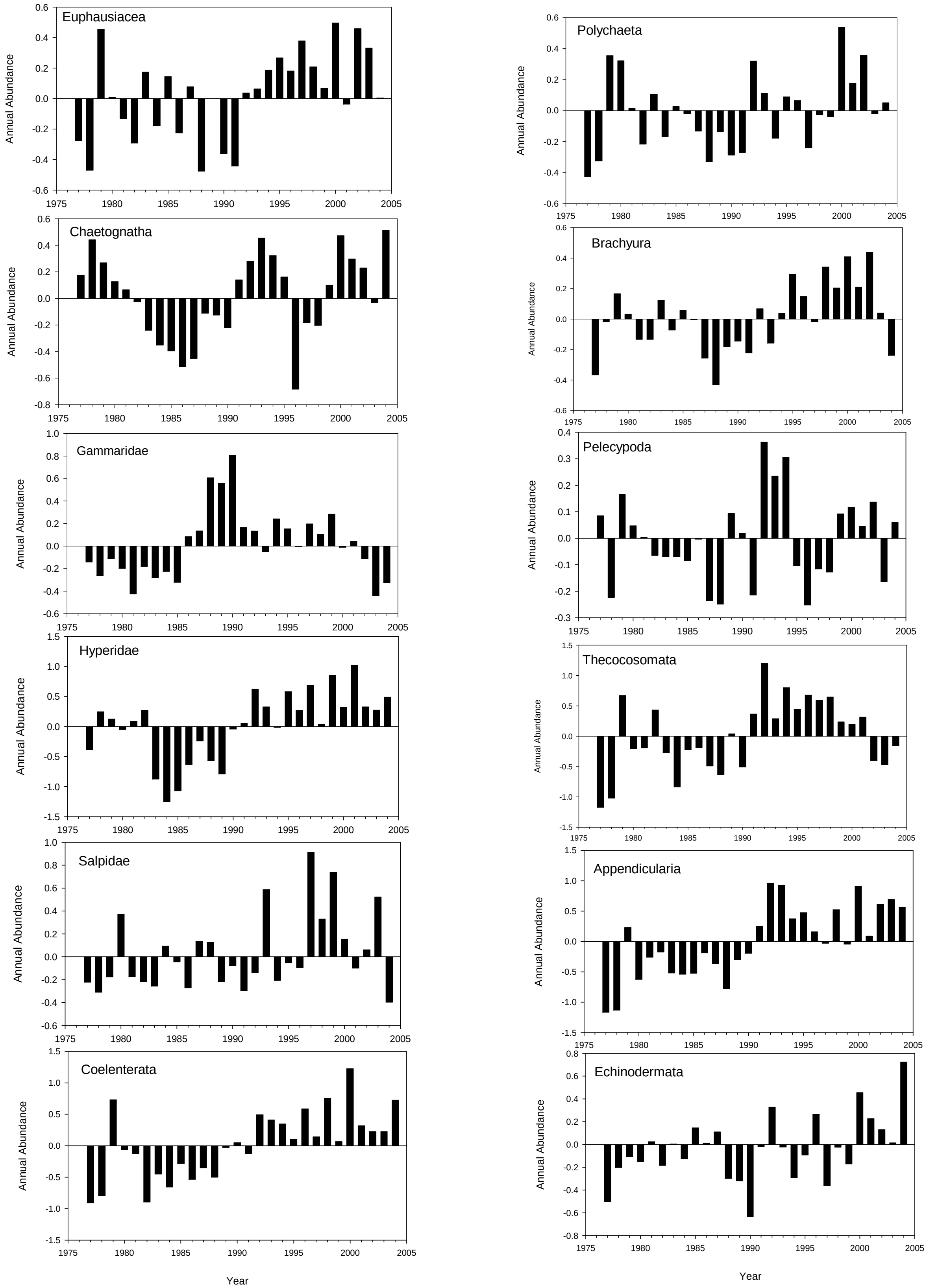


Figure 2.1.11. Annual abundance anomalies of common zooplankton taxa on Georges Bank from 1977-2004.

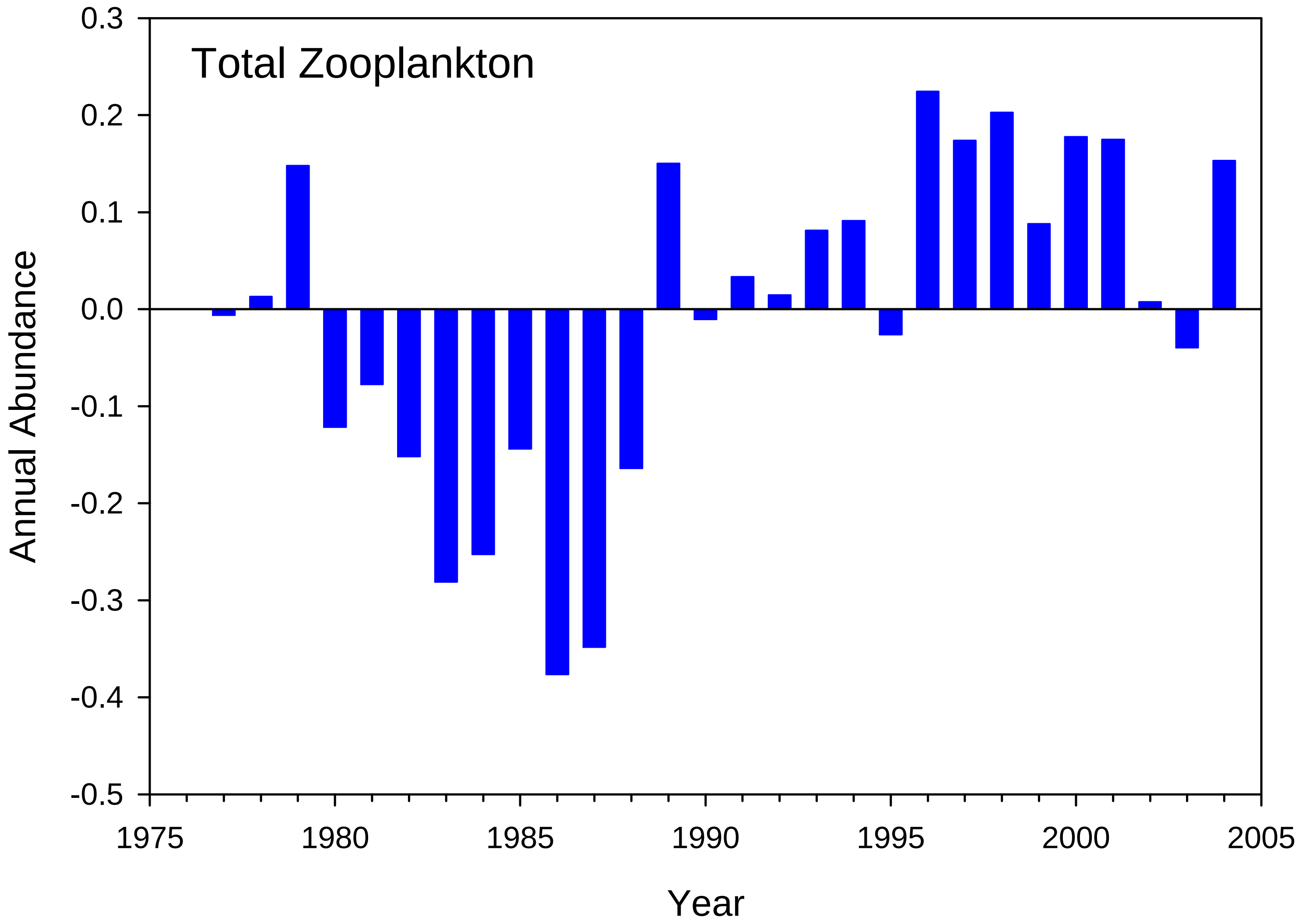


Figure 2.1.12 . Total zooplankton abundance anomalies on Georges Bank from 1977-2004.

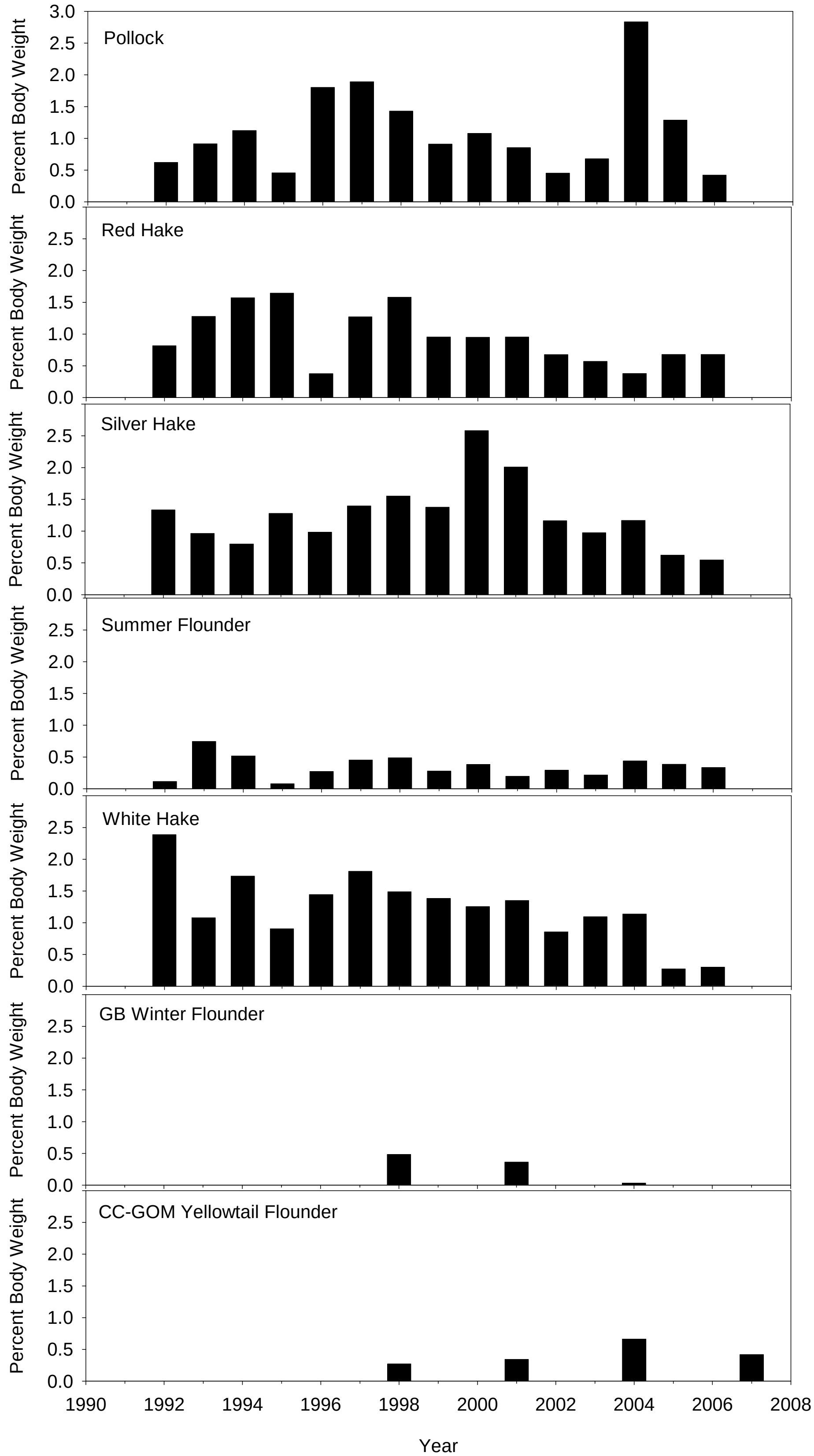


Figure 2.1.13 . Percent body weight of pollock, red hake, silver hake, summer flounder, white hake, Georges Bank winter flounder, and Cape Cod-Gulf of Maine yellowtail flounder, during the spring from 1992-2007.

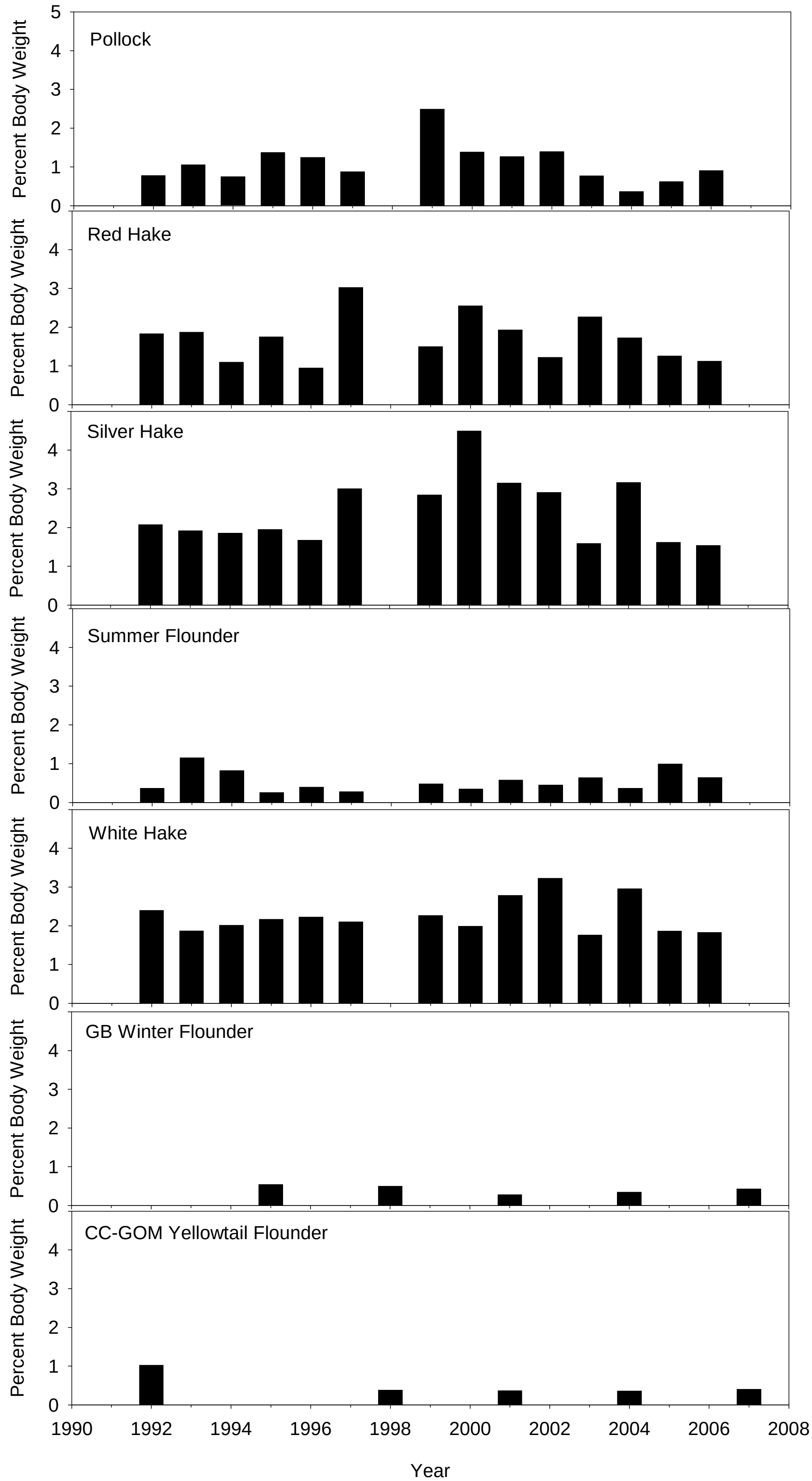


Figure 2.1.14. Percent body weight of pollock, red hake, silver hake, summer flounder, white hake, Georges Bank winter flounder, and Cape Cod-Gulf of Maine yellowtail flounder, during the fall from 1992-2007.

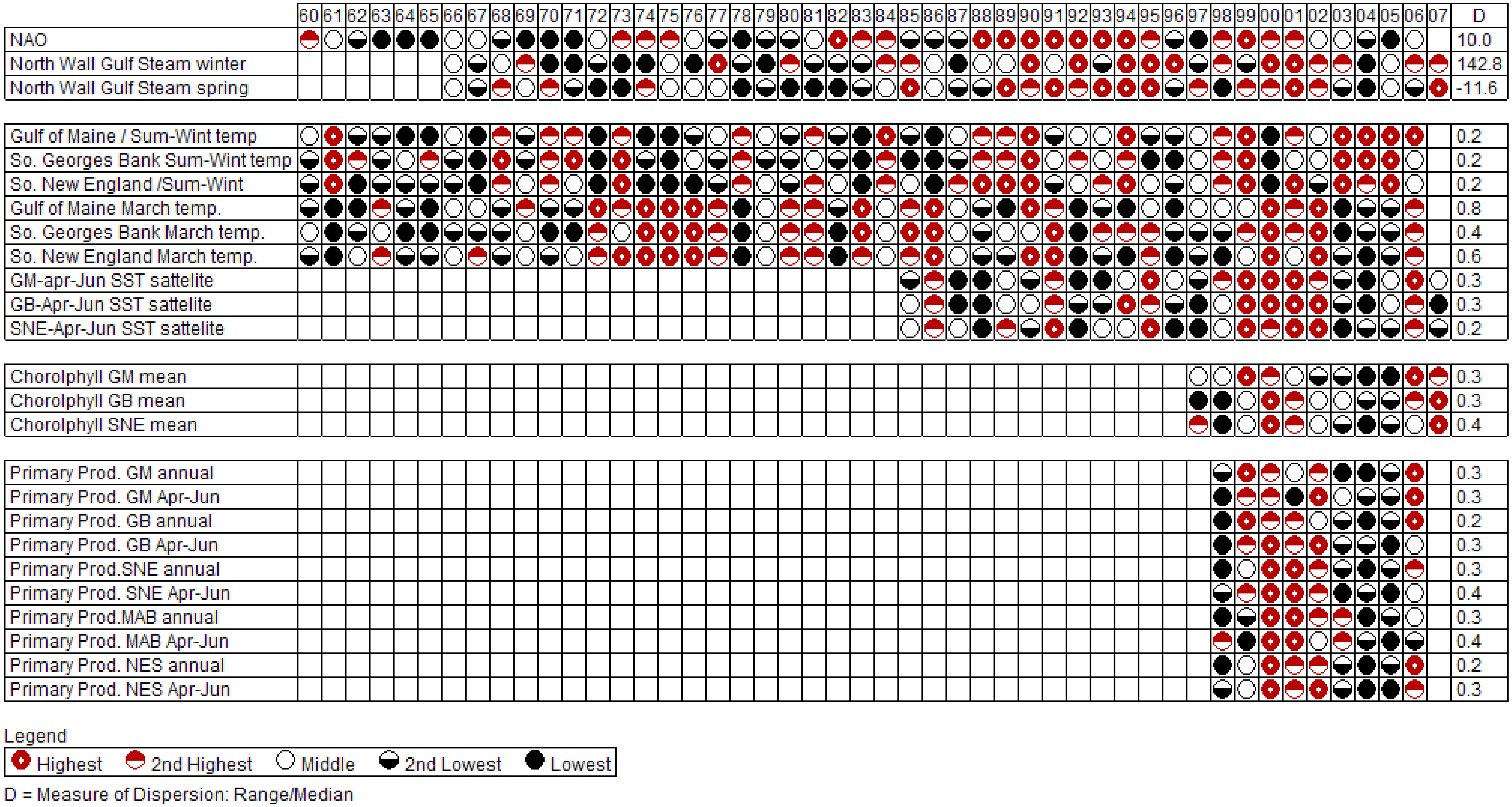


Figure 2.1.15 . Quintiles of environmental data including NAO, North wall of Gulf Stream, Sea surface temperatures, chlorophyll a, primary productivity, during 1960-2007.

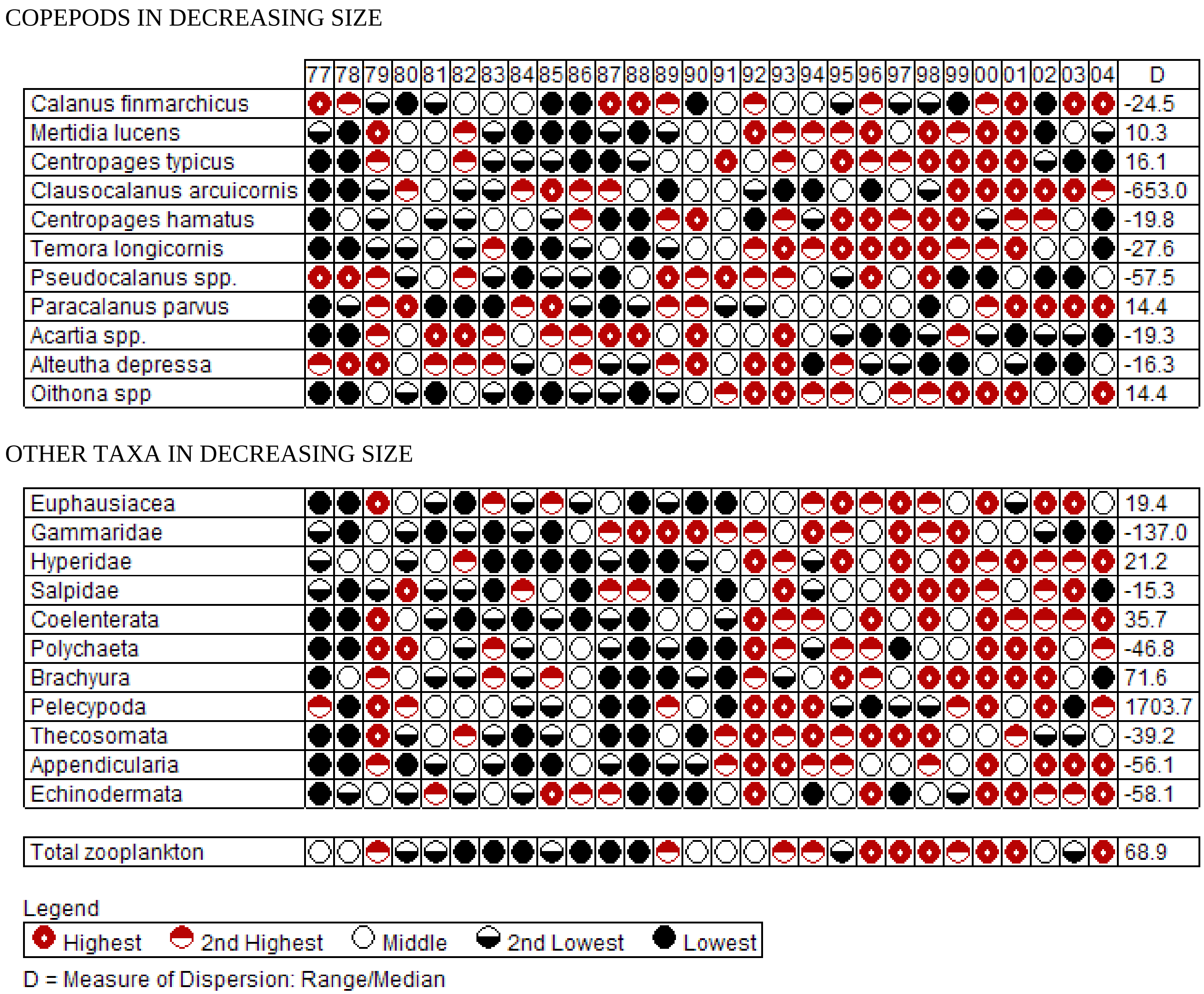
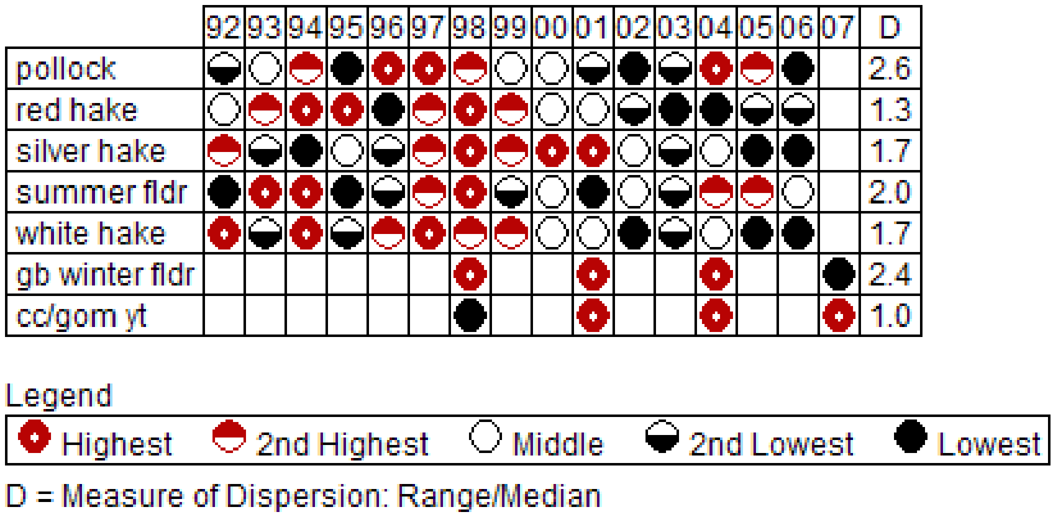


Figure 2.1.16 Quintiles of Georges Bank zooplankton anomalies, 1977-2004.

Spring Percent Body Weight



Autumn Percent Body Weight

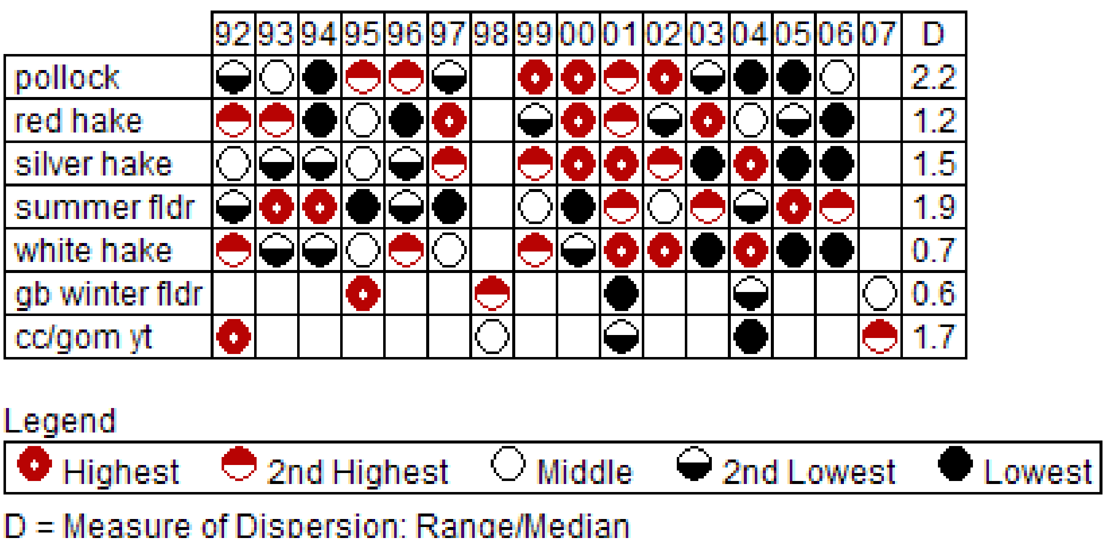


Figure 2.1.17 . Quintiles of percent body weight of six groundfish species from NEFSC spring and autumn research surveys, 1992-2007.